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MEASURES OF NAVY PILOT WORKLOAD, SLEEP AND PERFORMANCE IN STRESSFUL ENVIRONMENTS

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Measures of Navy pilot workload, sleep and landing performance collected under two stressful environments--carrier deployment and carrier landing qualification are analyzed and described. The study was conducted to demonstrate the application and utility of data collection techniques in operational environments and to describe the typical workload and sleep activity of Navy pilots. Attack pilots and LSOs averaged 12-hour workdays at sea and supplemented their sleep by short naps during flying periods. next page

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Landing performance for attack aviators was remarkably high with boarding rates at night averaging 93 percent for the entire deployment. Performance decrement was noted both day and night only after extensive in-port periods of flight inactivity. Recommendations and summary data are discussed.

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MEASURES OF NAVY PILOT WORKLOAD, SLEEP AND PERFORMANCE IN STRESSFUL ENVIRONMENTS

INTRODUCTION

The search for easily applied techniques that could be used by flight surgeons to assess the flight status of pilots operating in stressful environments has been the cornerstone of several psychophysiological research projects (1,2). While it is idealistic to expect that such techniques would be readily identified, it has been possible to define, measure and categorize a host of interrelated variables thought to be relevant to pilot performance effectiveness in stressful environments.

Pilot performance, blood chemistry, emotionality, and sleep data have been collected during combat operations off the Vietnam coast during the last stages of conflict and have provided some interesting information in this regard (3,4,5). Results of those preliminary studies indicate that changes in certain psychophysiological variables can be related to variations in pilot landing performance. A statistically significant multiple correlation was obtained with four predictor variables which accounted for sixty-four percent of the performance criterion variance. The general conclusions of the interdisciplinary research support the contention that integrated sets of physiological, psychological, sleep and demographic data collected with a valid and reliable criterion of pilot performance are useful in understanding combat-related stress.

The availability of a previously validated performance criterion has greatly facilitated such research (6). Aviation performance effectiveness was defined and standardized for the combat operations by use of a Landing Performance Score (LPS) criterion. In these carrier studies three basic measures were used to describe the pilot environment. First, measures of pilot landing performance were recorded during a nine-month combat deployment off the Vietnam coast. Second, physiological measures of stress as indicated by blood biochemistry were obtained during four time periods of the combat cruise to describe pilot reactions to variations of flight workload. A third category of pilot-related variables was that of sleep, pilot emotionality and pilot experience data. Pilot mood data were collected concurrent with biochemical data (four times); sleep data were obtained during one seven-day cruise period; and pilot experience and biographical information were collected prior to the cruise to obtain baseline estimates of pilot background information. Those variables formed the basis of a measurement scheme designed to integrate performance, physiological, psychological, sleep and experience data into a comprehensive description of the influence of a combat environment on Navy fighter pilots.

BACKGROUND

The practical significance of this research lies in the systematic attempt to measure and understand a number of variables that reflect a pilot's temporal state of readiness. While other research studies have examined some of these variables (7,8), the multidimensional approach recommended by Gartner and Murphy (9) and the practical sleep and work-rest research suggestions by Woodward and Nelson (10) spurred and supported this particular type of approach.

Background information taken from the combat research succinctly summarizes the present research status:

> Although the combat studies were exploratory in nature, they represented a preliminary investigation of over 60 pilot-related variables that were thought to be of potential interest in medically defining the combat environment for highly trained Navy aviators. Considerable time and analysis were given to the search for meaningful variables that could be used to reflect variations in pilot performance. A practical rather than purely theoretical method was used. By promoting parsimony the number of variables was reduced to a more manageable and definitive list and a better grasp of the interrelations between and among stress, sleep, workload, mood, experience and pilot performance effectiveness was obtained.
>
> To depict how temporal predictor variables interact during combat performance a simplified model was developed to account for the interrelations encountered in the data. That model is shown in Figure 1. In the investigations, pilot landing performance was predicted from a relatively small array of variables with various levels of success for different operationally defined pilot workloads. Five out of six multiple correlations were significant at the .05, or .01 level ranging from a high of $R=.84$, $n=25$ ($p<.01$) to a low of $R=.63$ ($p<.05$).
>
> The variables were arranged in the model for descriptive and integrative rather than predictive purposes. The model serves to depict sequentially the interactive effects obtained from the combat data analysis. It was found that a combat situation results in a pilot arousal level that is influenced not only by sleep but also by a pilot's specific aircraft experience. Both variables intervene in a complex manner to affect a pilot's emotional level and blood biochemistry. Specific arousal levels

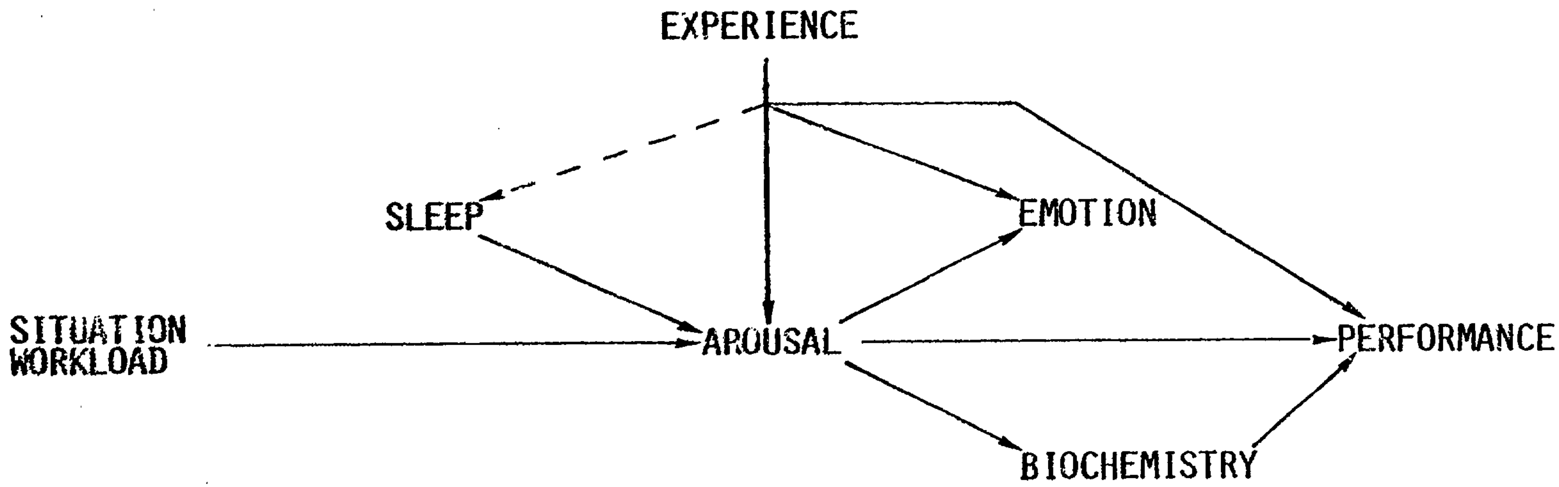

Figure 1. Pilot behavior arousal model predicting landing performance from measures of biochemistry, sleep, mood, emotions and experience.

were measured and described as a function of changes in sleep, workload and emotionality from baseline pilot data recorded during a non-stress period. This result is reminiscent of Helson's (11) theory of adaptation where changes in mood or affective levels are reflected by behavior performance changes in a given combat situation. Relative pilot experience also appears to influence a pilot's initial capability to perform effectively early in the cruise.

In summary, pilot adaptation to stress which accumulates during prolonged flight operations appears to be facilitated by experience. As cumulative workload increases for experienced pilots they sustain a high level of performance while decreasing their cholesterol and feelings of depression. For inexperienced pilots as workload increases they improve their landing performance at a cost of continuing high levels of cholesterol and feelings of depression and fear. An increase in inexperienced pilot performance is obtained at greater physiological and emotional cost than that reflected by identical measures for experienced pilots. For experienced pilots the adaptation to cumulative performance demands apparently results in a gradual decline in biochemical and emotional expenditure. It is as if pilots with experience adapt to stress and high workload while maintaining high performance. Inexperienced pilots, on the other hand, seem to require greater physiological and emotional energy to acquire the same performance as experienced aviators.

At present the model is suggestive of macroscopic interrelations between variables which can be used for data collection and categorization in future research efforts. (1)

Based on evaluation of the combat research and the ensuing model, it was concluded that more emphasis should be placed on pilot sleep, workload and performance data and that these data should be collected across different stress environments. This report covers the application and expansion of the research approach to two additional stressful environments normally encountered by Naval aviators. These two environments were aircraft carrier deployment to the Mediterranean Sea and carrier landing qualification (CQ).

METHOD

Samples

Two stress environment samples were selected for the collection of pilot temporal activity data and carrier landing performance data.

1. Carrier Deployment -- Data were collected aboard the USS Kennedy (CV-67) during a scheduled seven-month deployment to the Mediterranean Sea. Flight activity consisted of eight line periods over seven months during which day and night carrier recovery operations were conducted. Line periods averaged 8 to 18 days in length and resulted in two to four hundred average flight hours per line period. There were no hostile actions during the cruise and it was considered representative of a normal peacetime operational tempo.

2. Carrier Qualification -- Pilot data were obtained at VA-174, Cecil Field, Florida during two carrier landing training classes covering about three to four weeks per class. During this time frame pilots averaged 40 day and 90 night final approaches in preparation for CQ which consisted of up to 20 day and 12 night carrier landings over a three to four-day period of high intensity carrier recovery operations.

Subjects

1. Carrier deployment data were collected from 31 Navy pilots who flew the A7B (two squadrons) and A6E (one squadron) attack aircraft during a seven-month cruise aboard the USS Kennedy (CV-67) stationed in the Mediterranean Sea. All pilots were volunteers. Pilots were considered representative of a typical deployed squadron. On the average, across the three squadrons, pilots had 1450 flight hours in jet aircraft, 75 carrier landings and over seven years experience as Naval aviators.

2. Carrier qualification subjects included in the study were 11 Category I (first-tour) Replacement Pilots (RPs). The pilots were entering the final phase of training in the A7E Corsair II single-seat attack aircraft prior to joining a fleet squadron. Additional data were obtained from two instructor Landing Signal Officers (LSOs) in charge of the training. A total of 168 RP and 36 LSO man-days are included in the analysis. Shipboard carrier

qualification (CQ) periods accounted for 36 RP and eight LSO man-days while the remaining time was pre-qualification field training (FCLP).

Data Collection Periods

1. Activity data were collected during three major periods in the Kennedy deployment. Initial information was obtained during a nine-day transit from the United States to the Mediterranean Sea in January 1977. This has been termed the "Baseline Period," since it represented a time of no general flying. A second data collection effort was carried out during the last at-sea period in July 1977, and has been termed the "Followup Period." This followup period was characterized as one of relatively high pilot workload, as indicated by the amount of time per day devoted to flying and flight-associated tasks. A third assessment period, 72 hours of continuous flight operations within the Followup period, was also studied as a "High-Workload Period."

2. Data were obtained during FCLP and CQ periods of training at VA-174. Both periods represent times of intensive training activity and stress for all concerned. FCLP training involves many consecutive nights of landing practice followed by meticulous debrief of landing difficulties. Days are often devoted to simulator flights, lectures, and day landing practice on the field. Since the training must be responsive to any changes in carrier scheduling, many classes train on weekends and holidays as well. CQ usually covered from three to seven days, but is characterized by delays and schedule changes that force RPs to be on alert or flying for long hours at a stretch. Qualification landings themselves represent varying degrees of high stress for both RP and LSO alike. These pressures are intensified at night.

Data Collection Instruments

The following instruments were used to collect data on pilot acitivity, sleep and performance. Samples of the logs can be found in the Appendix.

Daily Activity Log. A daily log of all pilot activities was kept for each 24-hour period for each of the three data collection periods. The log consisted of 1/2 hour time segments from 0800 to 0800 and covered day and night activities. Logs were filled out throughout the day, just prior to sleep, or on arising. Activity examples included flying, pre/post-flight work, squadron work, eating, sleeping, exercise and all other non-work activity. A pilot simply put in a code number for each activity engaged in during a 24-hour period. Logs were collected daily. Slight variations were made in the log to accomodate Landing Signal Officer (LSO) "waving" activity. Otherwise, the logs across samples were identical.

Sleep Log. The sleep log was filled in upon arising every morning. It consisted of those portions of the daily activity log that were marked as sleeping or naps as well as questions of sleep quality and the amount of time it took before falling asleep. Sleep activity was measured on the following dimensions.

1. Total Sleep: The amount of sleep accumulated in a 24-hour period, regardless of the number of sleep periods. Average amounts over several days as well as frequency distributions of daily totals are reported when relevant.
2. Sleep Episode Duration: Frequency distributions of the duration of individual periods of uninterrupted sleep are reported when relevant. These periods of sleep can be roughly divided into short (3 hours or less) "Naps" and longer "Night's Sleep" episodes.
3. Sleep Activity: Distributions indicating the percentage of a group of subjects who had reported being asleep at a given time of day are included as indicators of patterns or habits in daily sleep. Each day is divided into 48 half-hour segments and distributions cover the 24-hour period from 0800 to 0800. Relative frequencies are calculated for the number of man-days reporting sleep at a given half-hour segment relative to the total number of man-days covered in a sample.

4. <u>Sleep Quality</u>: Two questions were included on the daily activity questionnaire that related to the quality of sleep obtained over the previous night. These questions were:

- "How much trouble did hou have getting to sleep?"
- "How well rested do you feel?"

Answers were limited to a four-point scale. Sleep was analyzed by quality on an OK or Not OK basis. If pilots indicated that they had "moderate" or "considerable" trouble getting to sleep or indicated that they felt only "slightly" or "not at all" rested sleep quality was considered non-recuperative or Not OK.

Performance Data

Landing Performance Scores. Landing performance data for all subjects consisted of Landing Performance Scores (LPS) which are objective measures of the quality of each landing based on a five-point scale. LPS scores are based on final landing outcomes. By obtaining LSO estimates of the relative weights for each landing category the following criterion scoring system was devised.

The LPS

Landing Categories	Rank Order	LSO Scaled Landing Score Intervals
Wire 3 (target)	1	6.0
Wire 2	2	5.0
Wire 4	3	4.5
Wire 1	4	3.5
Bolter	5	2.0
Own or technique waveoff	6	1.0

The derivation, reliability and validity of the LPS as a criterion measure is well documented (6). The LPS represents an equal interval scale of landing quality that reflects an LSO concensus of the relative numerical value of each possible landing outcome. The LPS data source is the LSO landing log which identifies each landing attempt by time, pilot, aircraft, weather, glideslope, LSO, lighting and terminal landing outcome.

<u>Boarding Rate</u>. Boarding rate is a second criterion and consists of the percentage of carrier approaches that result in successful wire arrestment. Bolters and technique waveoffs represent unsuccessful approaches. Landing log data are analyzed to determine the boarding rate statistics for both day and night approaches. By itself, boarding rate is a simple, objective index of relative success in carrier landing and is frequently used as an operational measure of landing effectiveness.

<u>Wire Arrestment</u>. Wire arrestment distributions are a third criterion. The number three wire is the target wire and represents the ideal landing outcome under normal circumstances. Deviations from the ideal are reflected in wire arrestment distributions which in turn represent deviations from established safety and engineering standards for carrier aircraft.

<u>Analysis Structure</u>

1. The deployment data analysis has been divided into two major portions, the first covering temporal variables (activity data, workload and sleep), and the second dealing with landing performance measures. Comparisons across three data collection periods--Baseline, Followup and High-Workload--are presented. Conclusions are listed at the end of each section, and overall recommendations are advanced at the end of the second section.

In the Kennedy sample, it was found that the differences between squadrons in activity variables were minimal. In the interests of clarity, therefore, most of the comparisons of temporal variables between Baseline, Followup and High-Workload periods are presented on the basis of aggregate statistics for all three VA squadrons combined.

2. Sleep and workload temporal data collected for CQ training are compared over both groups of subjects (RPs and LSOs) and for both major training phases (CQ and FCLP).

- During FCLP (RP vs LSO)
- During CQ (RP vs LSO)
- For RPs (FCLP vs CQ)
- For LSOs (FCLP vs CQ)

Additional comparisons of activity and sleep patterns refer to findings of similar studies of different groups within the Navy community. Specific comparisons are made with:

- Naval attack aviators from the carrier deployment sample
- Navy personnel assigned to a shore activity
- Navy ship crew members during combat activity

These comparisons will provide some perspective in assessing the patterns of sleep and daily activity for the CQ study sample.

RESULTS

Carrier Deployment Sample: Pilot Temporal Variables

Work/Nonwork Allocation. Investigation of pilot daily activity logs focused on the comparison of time allocation between work and nonwork during each of the three time periods. The overall classification of "work" included flying, flight-associated work (such as briefings, preflight, etc.), and squadron work (required administrative and operational tasks not directly involved with flying). "Nonwork" included eating, sleeping, exercise, and a broad category of "other nonwork" which covered general leisure activity. Table 1 shows the mean number of hours per day allocated to work and nonwork during the three study periods. Although the high workload period was the most extensive period of flying in the entire cruise, only a slight increase in total work hours over the Baseline and Followup was observed. Attack pilots consistently worked 12 hours per day regardless of the study period.

TABLE 1. WORK AND NONWORK HOURS FOR THREE TIME PERIODS.

Period	N(men/man-days)	Hours	
		Work	Nonwork
Baseline	20/136	12.0	12.0
Followup	21/164	12.4	11.6
High-Workload	21/63	12.7	11.3

Figure 2 graphically displays this information showing the proportional breakdowns for the component activities within the work/nonwork categories. Table 2 shows this breakdown numerically, while Figures 3 and 4 display the differences in activity allocation between the Baseline and Followup periods, and between the Followup and High-Workload periods, respectively.

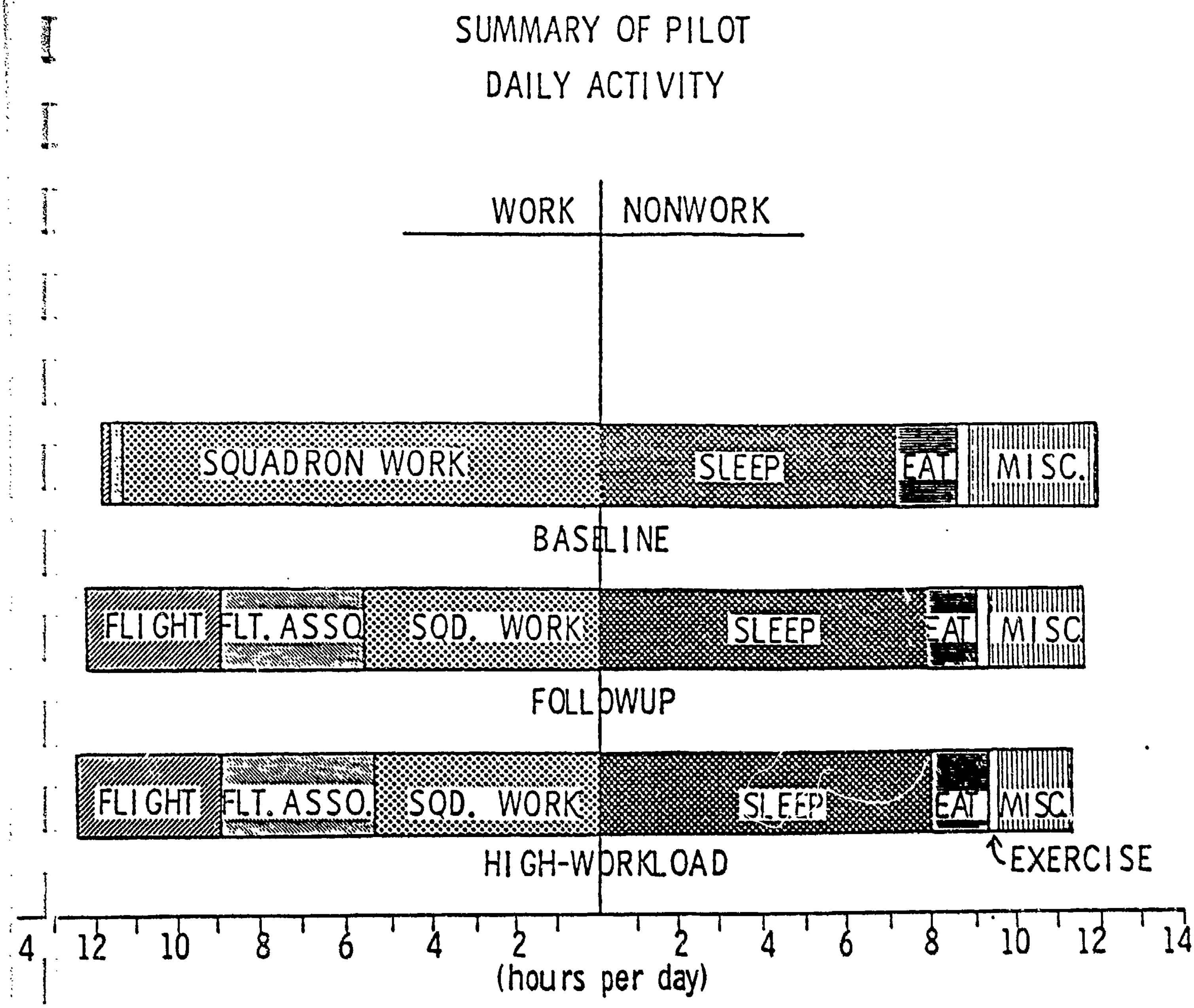

Figure 2. All VA Squadrons -- Daily Work/Nonwork Allocation for Baseline/Followup/High-Workload Periods.

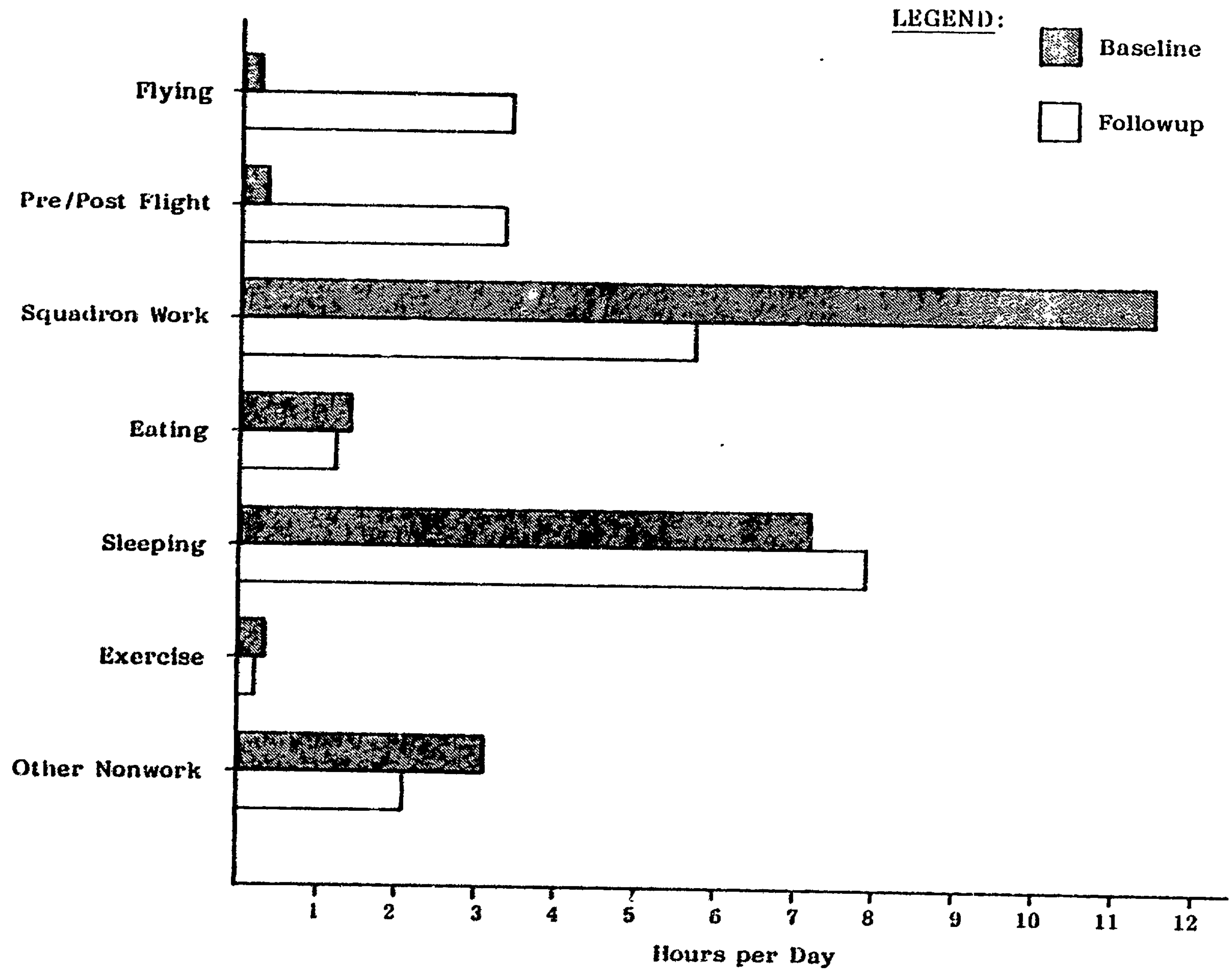

Figure 3. All VA squadrons -- Daily activity for Baseline vs Followup periods.

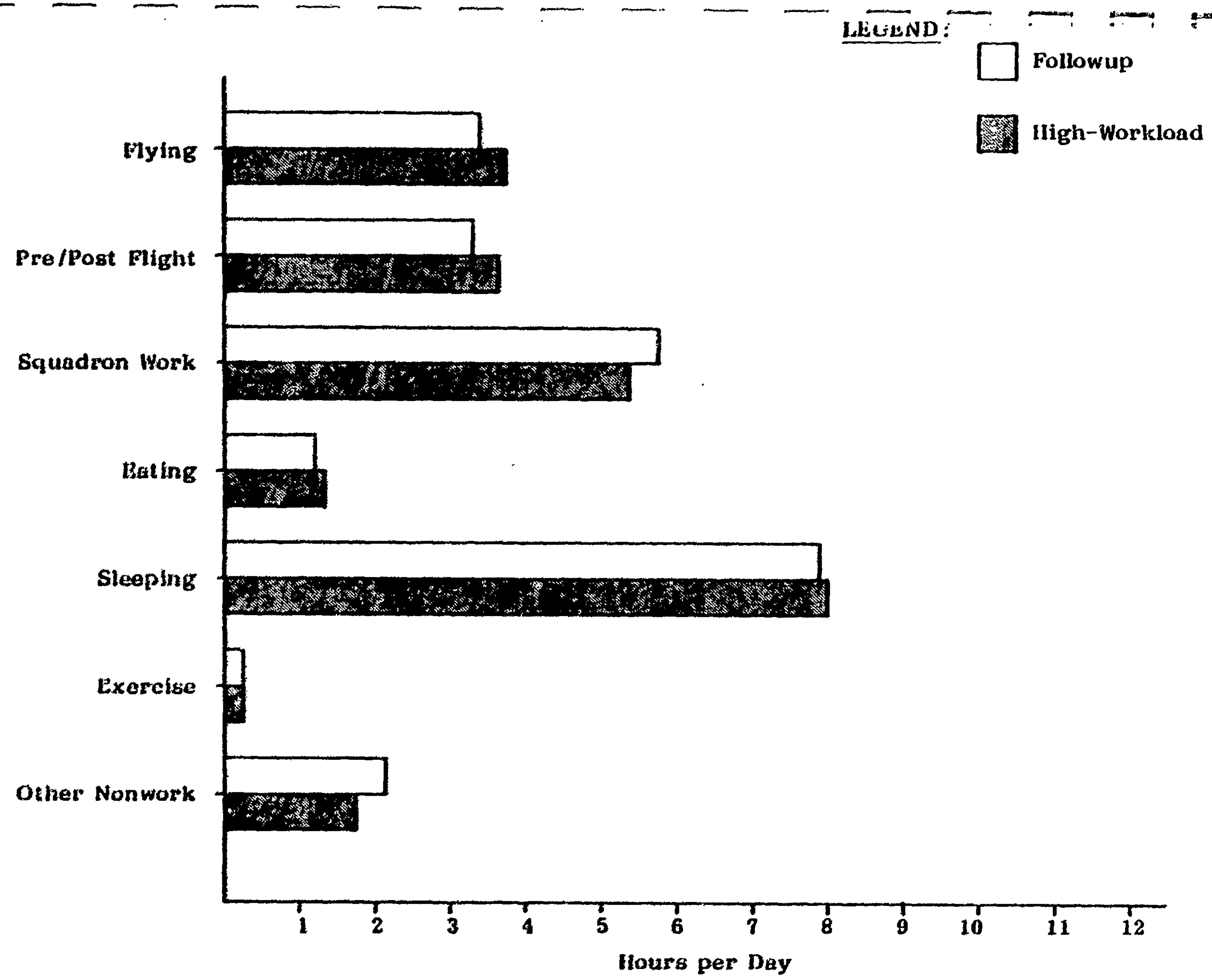

Figure 4. All VA squadrons -- Daily activity for Followup vs High-Workload periods.

TABLE 2. HOURS OF SHIPBOARD ACTIVITY
FOR THREE STUDY PERIODS

Period	N (men/ man-days)	Flt	Preflt	Sqd Wk	Eat	Sleep	Exer	Other Nonwork
Baseline	20/136	0.2	0.3	11.5	1.4	7.2	0.3	3.1
Followup	21/164	3.4	3.3	5.7	1.2	7.9	0.2	2.1
High-Workload	21/63	3.7	3.6	5.4	1.3	8.0	0.2	1.7

As can be seen, the only major difference between the three periods lies in the allocation of work hours between flight, flight-associated tasks, and squadron work. The number of hours per day devoted to work in general remained stable across periods. During periods of flight activity, squadron work decreased so that the overall amount of time allocated to work remained relatively unchanged. It should also be noted that the "High-Workload" period of continuous flight operations registers only a nine percent increase in flight and flight-associated work time. Investigation of flight records, however, revealed that the total daily flight tempo (as measured by total hours flown per day) during the three-day "High-Workload" period increased only nine percent as well. Work/nonwork allocation for all three periods shows only slight variations. Characterization of the Followup period as one of high pilot workload would have to be on the basis of number of hours devoted to flight activity alone; further, it would seem that the so-called "High-Workload" period does not cover a significantly different pilot workload demand than the regular flying period.

Sleep Indicators. A second broad category of temporal indicators involved sleep habits and other sleep-associated factors. Analysis of these variables included investigation of the amount of sleep reported per 24-hour day, and the inter-sleep interval -- an indicator of the frequency of sleep episodes. The percentage distributions of pilot responses to two questions about their sleep quality were also studied to see if the increased tempo of operations and workload had any effect. Finally, distributions of certain sleep variables were compared for the Baseline and Followup periods, and were also contrasted with the distributions for an aircraft carrier crew for a similar operational period.

Table 3 shows the total sleep reported per 24-hour day and the mean interval between sleep episodes for the three study periods.

TABLE 3. TOTAL SLEEP AND INTERSLEEP INTERVAL FOR THREE STUDY PERIODS

Period	N (men/man-days)	Total Sleep (24 hr)	Intersleep Interval
Baseline	20/136	7.2 hr.	12.4 hr.
Followup	21/164	7.9 hr.	11.6 hr.
High-Workload	21/63	8.0 hr.	10.9 hr.

As can be seen, the amount of sleep per day actually rose only slightly for the high workload periods. The rather small drop in intersleep interval is indicative of a tendency to increase the frequency of sleep episodes during flying periods.

Tables 4 and 5 show the percentage distributions of responses to two questions about the quality of sleep, comparing these distributions over the three study periods. These figures are also presented in Figures 5 and 6.

TABLE 4. PERCENTAGE DISTRIBUTION OF ANSWERS TO QUESTION: HOW MUCH TROUBLE DID YOU HAVE GETTING TO SLEEP?

Period	N	None	Slight	Moderate	Considerable
Baseline	20	54.3%	25.5%	13.6%	6.5%
Followup	21	56.7	29.9	9.6	3.8
High-Workload	21	58.0	30.1	8.0	3.9

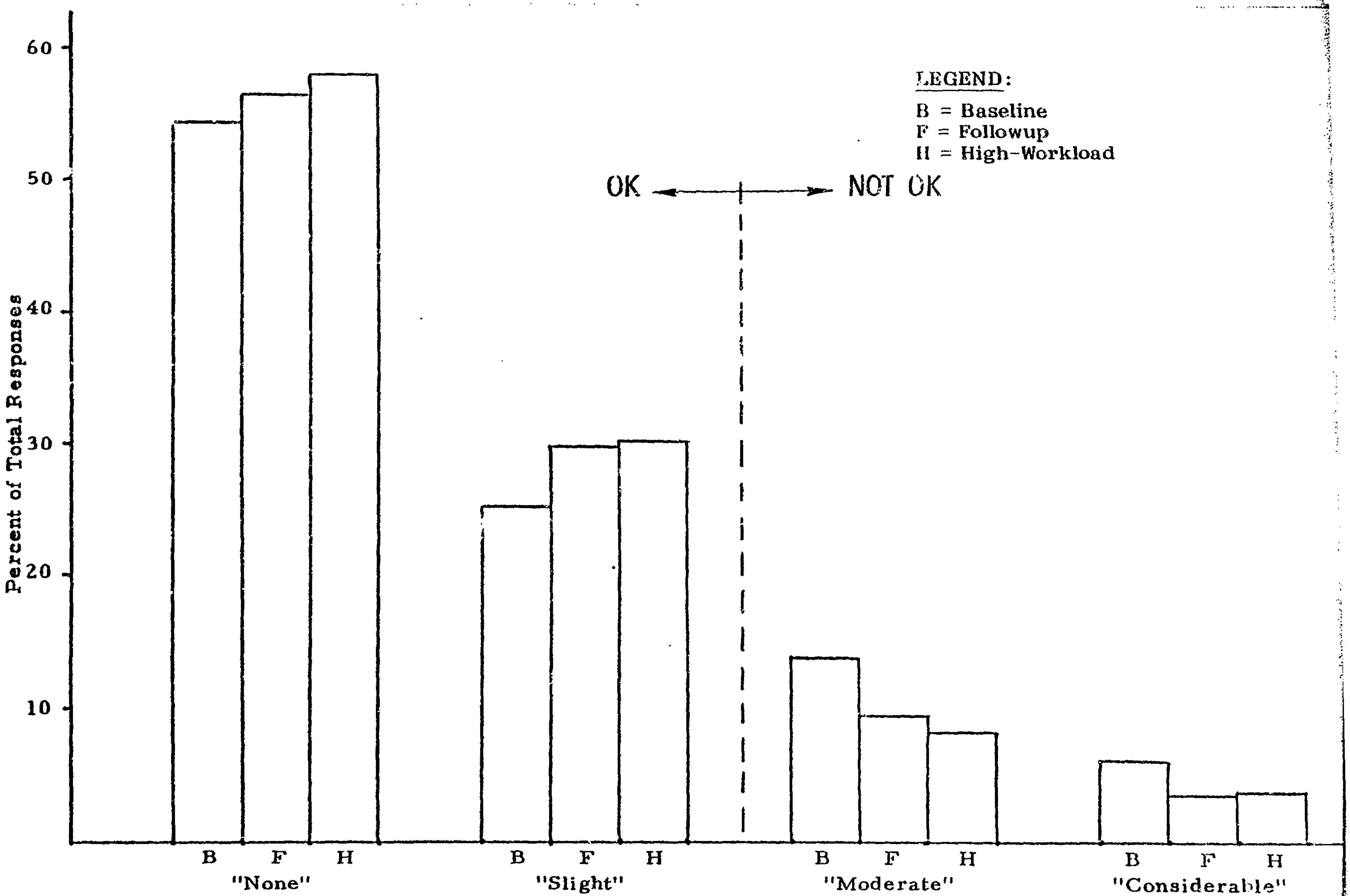

Figure 5. Percentage distribution of answers to question: "How much trouble did you have getting to sleep?" (All VA Squadrons)

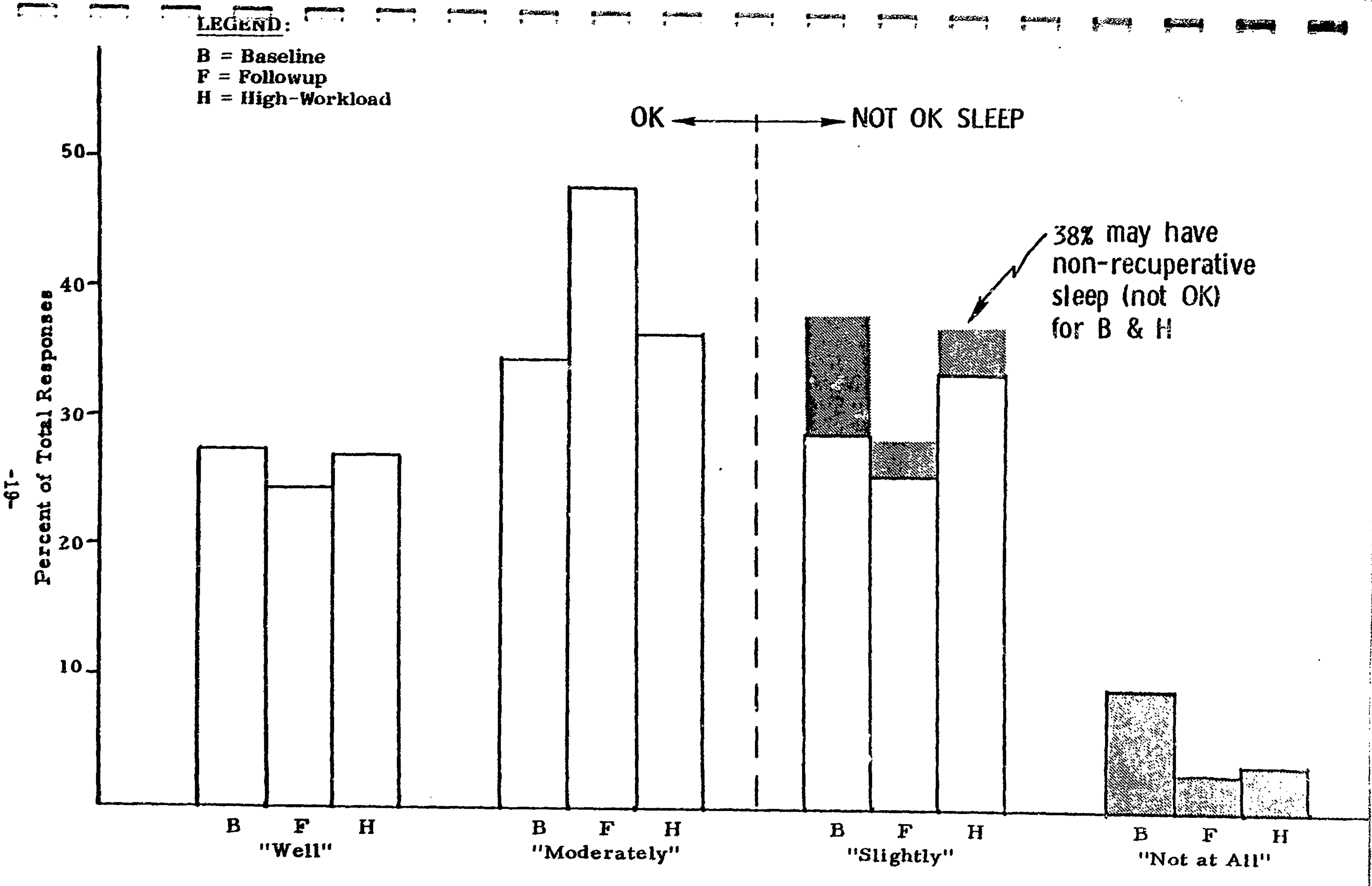

Figure 6. Percentage distribution of answers to question: "How well rested do you feel?" (All VA Squadrons)

TABLE 5. PERCENTAGE DISTRIBUTION OF ANSWERS TO QUESTION: HOW WELL RESTED DO YOU FEEL?

Period	N	Well	Moderately	Slightly	Not at all
Baseline	20	27.4%	34.6%	28.6%	9.3%
Followup	21	24.0	47.6	25.7	2.8
High-Workload	21	27.0	36.5	33.3	3.2

As can be noted from the tables and figures, all three periods show similar response patterns for both sleep quality questions. In Table 5 and Figure 6, which show the quality of sleep, about 38 percent of the pilots reported non-recuperative sleep during the Baseline and High-Workload periods. This is reflected by their answers to how well rested they felt if they replied "slightly" or "not at all." In contrast, only about 25 percent of the pilots felt "well rested" for any of the three periods. Whether this is a consistent trend for deployed pilots is not known but it is relatively consistent across periods and may be a pilot-shipboard phenomena.

Figures 7, 8 and 9 graphically depict three aspects of the distribution of sleep across the sample during the Baseline and Followup periods. The distribution of these variables for an aircraft carrier crew (labelled KITTY HAWK) are also displayed to provide characteristics of reference to a non-aviation sample.

Figure 7 shows the distribution of sleep activity over the 24-hour day by graphing the percentage of pilots who were asleep at any given hour. The rather peaked shape of the distribution for the VA squadrons Baseline period contrasts with the crew sample, which indicates that sleep was more evenly spread across the evening hours for the ship's crew who are all non-flying personnel. Note that fifty percent of the pilots were not asleep until early morning during the ship transit compared to about 2200 for the ship's crew. In general, pilots tended to retire and arise later than the ship's crew. The distribution of sleep for the Followup period more closely approximates that of the KITTY HAWK sample. The differences between the daily routines of ship's crew and pilots are evident in these charts. Most of the crew sample

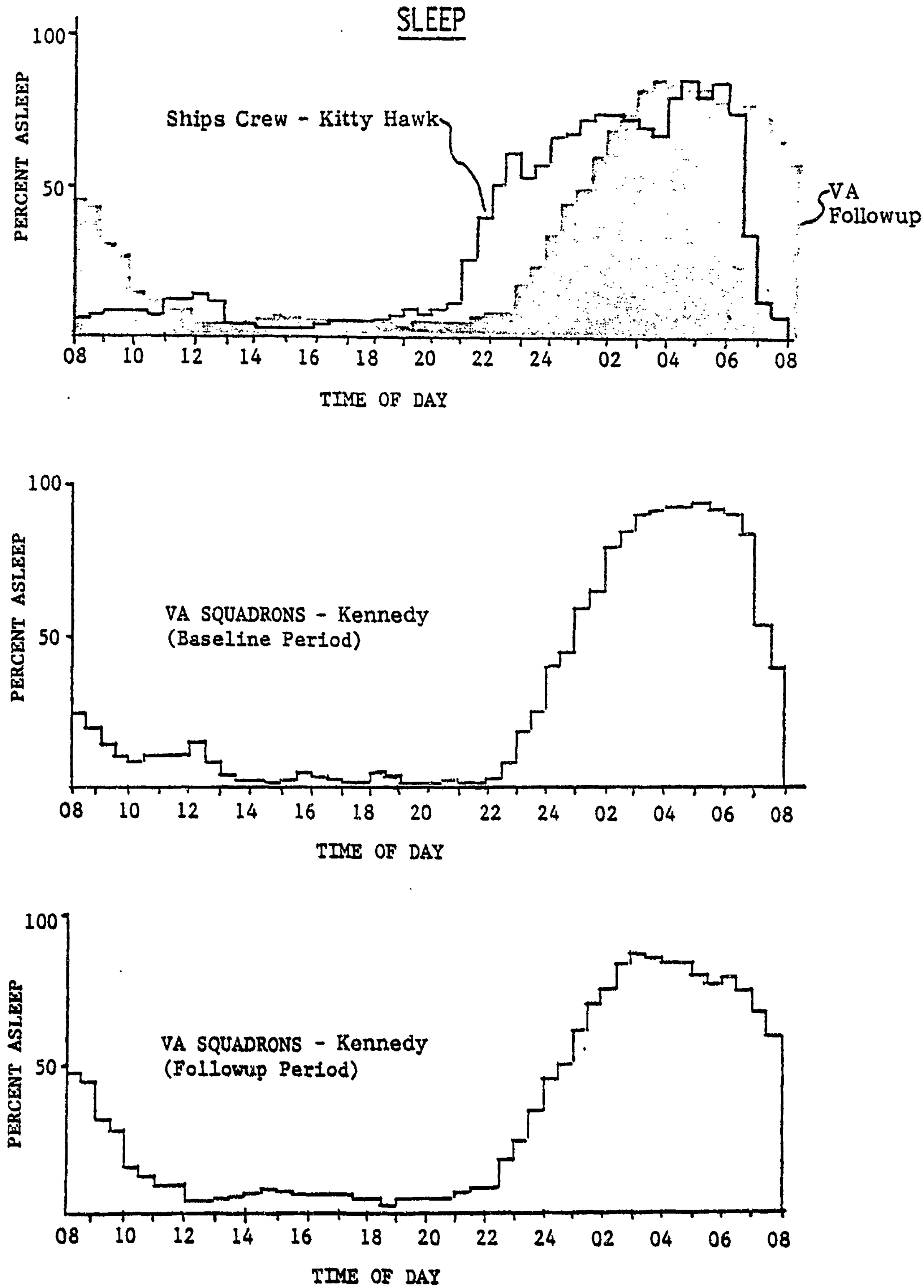

Figure 7. Sleep activity comparison for ship personnel and VA pilots.

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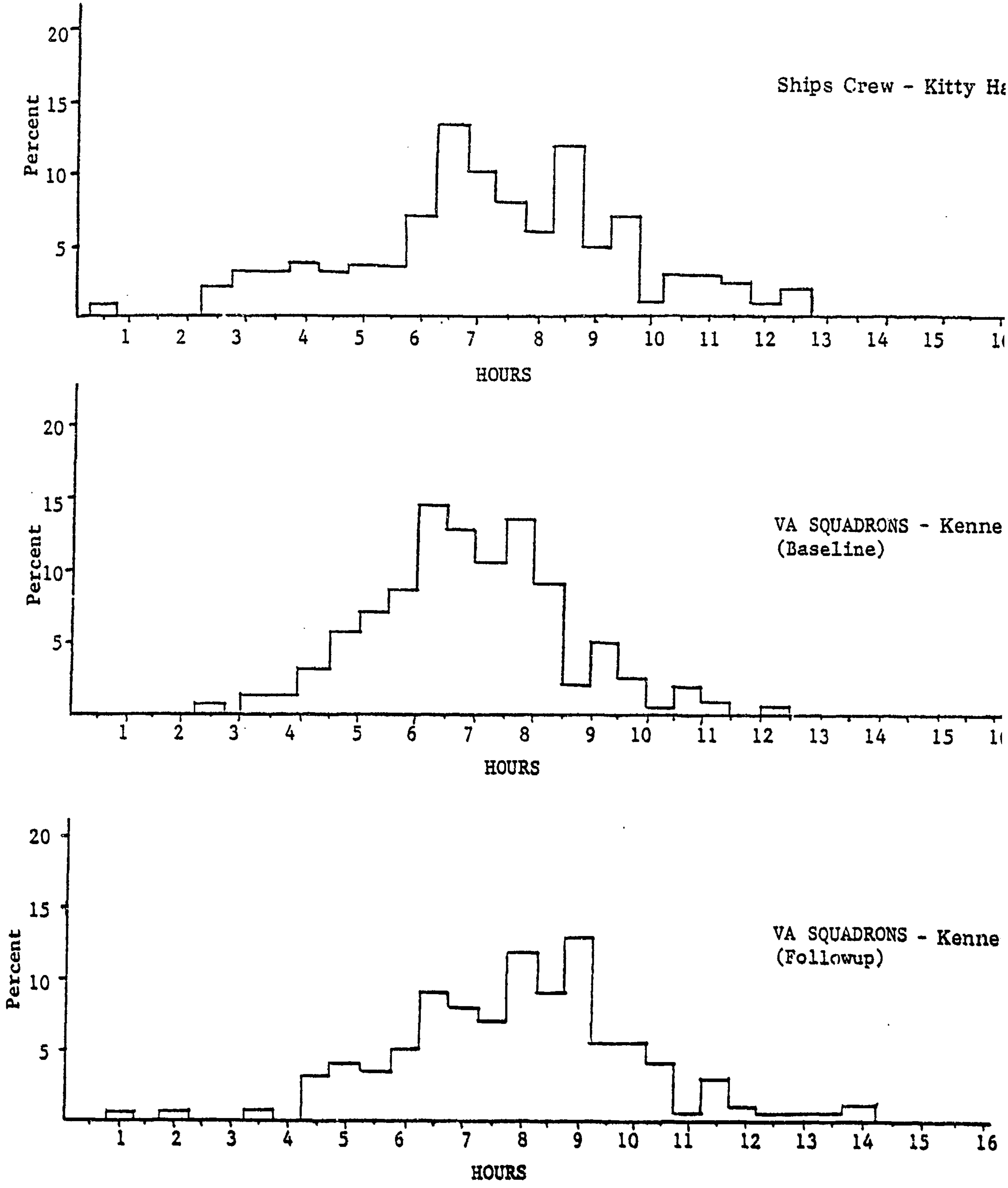

Figure 8. Total sleep in twenty-four hours for ship personnel and VA pilots.

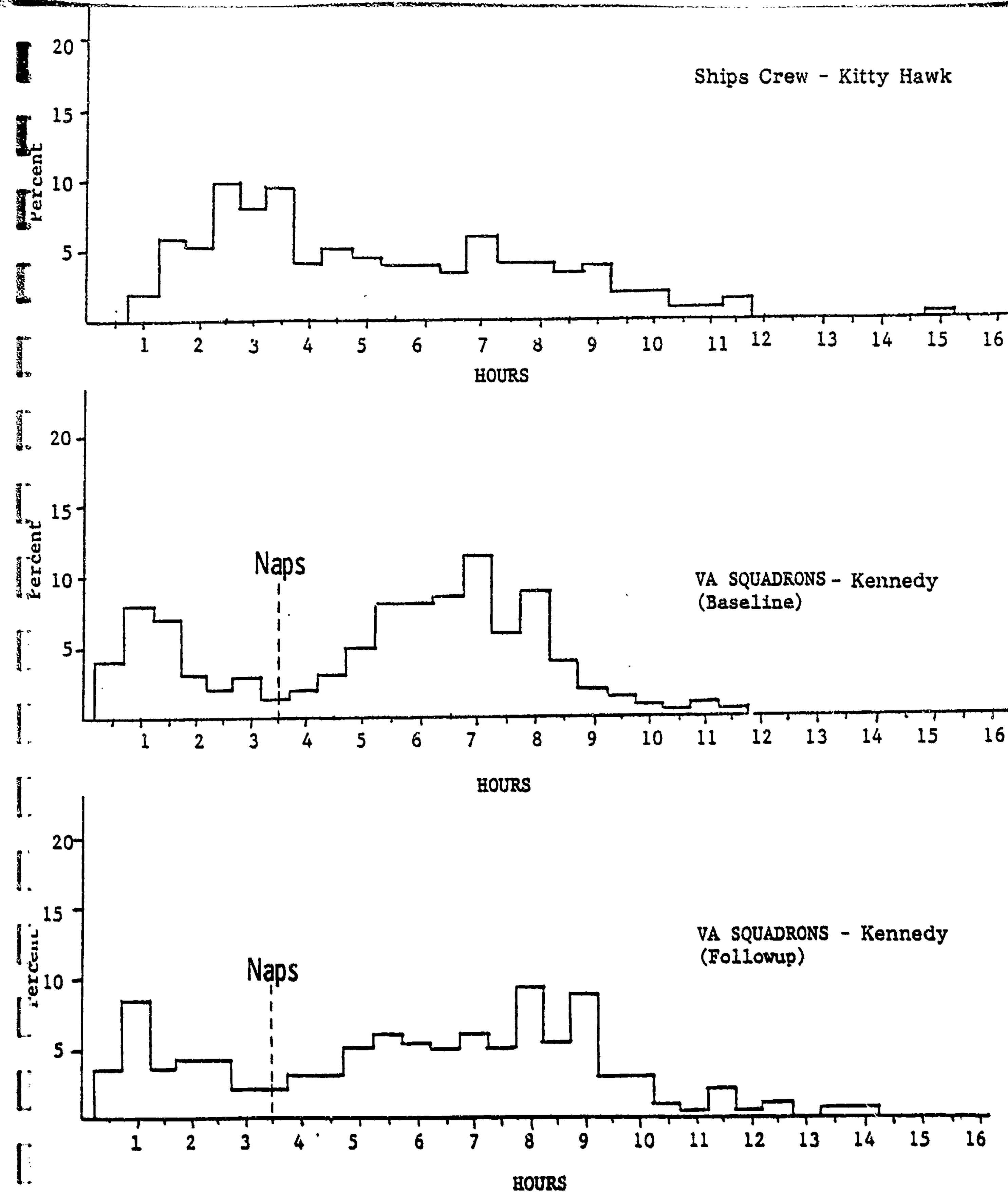

Figure 9. Sleep episode duration for ship personnel and VA pilots.

are awake before 0700, and less than ten percent are asleep at 0800, while most of the pilot sample is asleep at 0700, and nearly fifty percent are still asleep at 0800.

Distributions of Total Sleep obtained during a 24-hour period (Figure 8) again show only slight shifts between Baseline and Followup periods. The shape of the VA squadrons distribution for the Baseline period shows less variability than that of the KITTY HAWK group. The Followup period again more closely resembles the ship's company pattern.

Figure 9 shows the distributions of sleep episode duration. Here the KITTY HAWK sample shows distinct concentration toward the low end of the scale, with the distribution highly skewed to the right (high end), indicating that more personnel were sleeping for only short periods (3-4 hours) at a time. The distribution of the air wing (VA) sample, however, shows a bimodal pattern with peaks at about 1-1/2 hours at at 7-8 hours. These indicate that a pattern of short naps and longer "night's sleep" periods prevail among the VA squadron sample. The flattening of these peaks in the Followup period points to slight disruption of this pattern.

Not only are naps indicated for all groups but sleep also appears fragmented even during the Baseline transit period. This may be due to the unique shipboard routine of watches and work that make everyone "on duty" throughout the 24-hour day. The consequence of long work hours seems to be either frequent but short sleep episodes or longer episodes up to 14 hours for some VA pilots during the Followup flying period.

Summary: Carrier Deployment. The primary conclusion to be drawn from the work data is that the three periods selected to study workload effects did not differ significantly in terms of differential workload. It was found that attack aviators generally work 12-hour days aboard ship regardless of flight activity. Results show that during various workload periods aboard ship, attack aviators work long days regardless of flight schedules. Workload tends to shift merely between squadron administration and flight time depending on ship activity. Shipboard duty apparently dictates the length of work with only the nature of work showing differences. Allocation of time between work as nonwork activities was not substantially different for any of the three study periods. Although the number of actual hours of work did not change appreciably across work periods, flight related activities accounted for 57 percent of the normal 12-13 hour work day. Continuous (72 hour) flight activity resulted in only a slight increase in flight hours and sleep and apparently was not enough of a difference to cause any dramatic or significant changes in work or sleep activities. Because of the slight increase in work and sleep it is hypothesized that more days of continuous operations would tend to increase the observed effects and eventually might result in more significant disruption of the normal work/sleep cycle.

Sleep activity across the Baseline and Followup periods showed only slight shifts in patterns and amounts of sleep. The amount of sleep per day rose slightly (to 8 hours) for High-Workload periods and there was a tendency for pilots to take short naps during flying periods. About 38 percent of the pilots reported non-recuperative sleep during ship transit and high flight activity.

Perhaps the overall significance of the workload and sleep cycle data for carrier pilots lies in its initial documentation and description and its future use as a baseline reference system for other pilot workload or stress studies. Certainly the measuring instruments used to collect workload and sleep data appear readily adaptable for other types of operational application and have proved useful for categorizing as well as collecting pilot temporal data.

Carrier Deployment Sample: Landing Performance

Carrier landing performance was evaluated using the LPS and boarding rate over three time periods. Initial comparisons were made between performance over the entire cruise and that registered for the Followup and High-Workload periods. Performance was next broken down across eight of the extended at-sea periods (line periods) of the deployment to investigate long-term cruise trends. Last, in order to evaluate any performance degradation caused by extended inactivity, performance on the initial landings of the eight selected at-sea periods (following in-port periods of six to 17 days) were contrasted with the last landings made prior to in-port periods. In all the analyses outlined above, separate evaluations were made for day and night landings.

Landing Performance Scores. Since one purpose of the study was to investigate the possible effects of certain temporal variables on pilot performance, initial study centered around the comparison of performance between the Followup and High-Workload periods. Performance levels of the entire deployment were used as baseline references.

Table 6 shows the day and night Landing Performance Scores for all VA squadrons in the study sample. The information in this table is graphically presented in Figure 10. Full data and graphics are found in the Appendix.

TABLE 6. SUMMARY OF LANDING PERFORMANCE SCORES FOR ATTACK AVIATORS

	Overall Cruise		Followup		High-Workload	
	N	Mean	N	Mean	N	Mean
DAY						
All VA	1306	5.11	208	5.32	69	5.34
Norm = 4.78						
σ = .24						
NIGHT						
All VA	496	4.97	70	5.12	35	5.03
Norm = 4.55						
σ = .25						

As might be expected, the performance levels for night landings were somewhat lower than those for day landings. Performance levels during High-Workload are slightly higher for day landings and slightly lower for night than during the entire Followup period. The Followup period (which occurred at the end of the deployment) shows higher proficiency levels for day and night

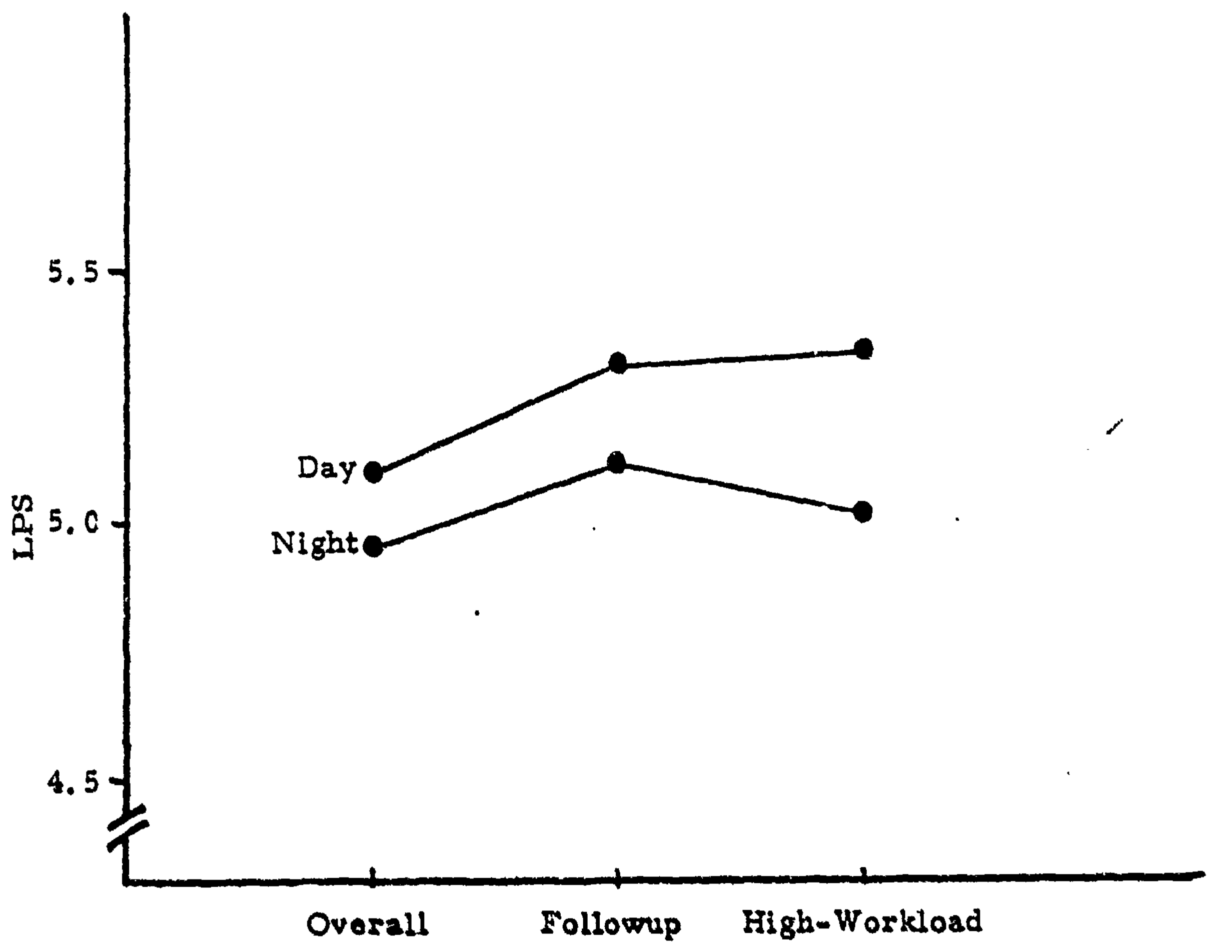

Figure 10. Landing performance scores for all VA squadrons.

when compared to the overall cruise levels. Based on normative data, the day performance for the overall cruise was at the 92nd percentile of all day carrier landings. Night performance was at the 95th percentile. These are extremely high performance levels and reflect a remarkably high landing performance effectiveness. Percentiles are even higher for the Followup and High-Workload periods and indicate the highest levels of landing performance yet recorded for a full cruise deployment.

Boarding Rate (BR). Boarding rate data were collected for the same time periods. Table 7 shows performance comparisons across evaluation periods using Boarding Rate (BR) as the criterion. Figure 11 displays this information graphically. More extensive boarding rate data for individual squadrons can be found in the Appendix.

TABLE 7. VA BOARDING RATES

	Overall Cruise	Followup	High-Workload
DAY			
All VA	0.95	0.96	0.97
NIGHT			
All VA	0.93	0.98	0.97

While differences in boarding rate between study periods and across squadrons are only slight, the boarding rates themselves are significant in that they are extremely high, and indicate a very high level of overall proficiency. By comparison, other studies of landing performance (6) reported typical day and night boarding rates of 0.85. Certain aircraft types have characteristically registered boarding rates as low as 0.75 over an entire cruise. Overall, the boarding rates achieved for the entire cruise and each workload period are the highest ever recorded for a deployment. Rates were consistently high for individual squadrons as well.

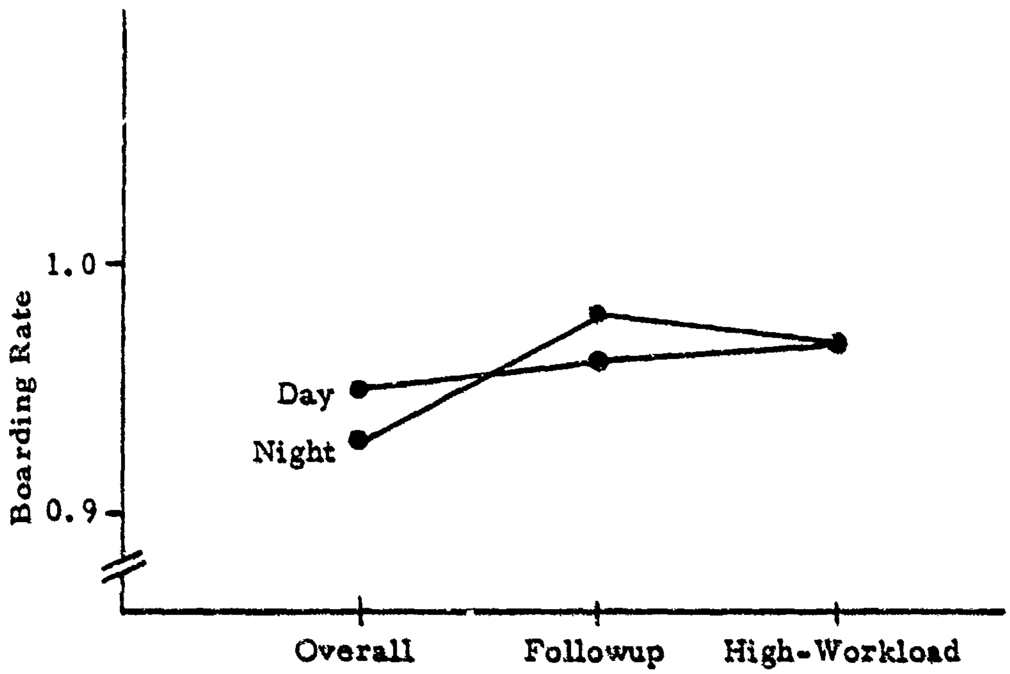

Figure 11. Boarding rates for all VA squadrons during carrier deployment.

Cruise Performance Levels. Pilot performance levels over the duration of the cruise were examined for trend information. Eight at-sea periods during the deployment were selected as being long enough to provide sufficient landing sample sizes. Performances of 34 pilots (including the 21 study sample subjects) were evaluated over each of the eight sequential "line periods."

A table of day and night landings, boarding rate, and mean LPS levels for the group is found in the Appendix. The overall high levels of proficiency for these VA squadrons are again noteworthy. Figures 12 and 13 display the aggregate sample landing performance across line periods using Landing Performance Scores (LPS) and Boarding Rate, respectively, to measure proficiency levels of those time periods.

A slight improvement trend from the beginning to the end of the cruise is apparent in the LPS but the consistency of the overall performance is also apparent. These observations remain valid for boarding rates as well. Although the night boarding rate fluctuates somewhat, these variations are only slight and attributable, at least in part, to the effects of a few poor approaches on the smaller sample sizes for night landings.

Performance Decrement Caused by Inactivity - Comparison of Performance Levels at Beginning and End of At-Sea Periods. In an effort to assess possible decrement in performance levels caused by prolonged carrier landing inactivity (such as an extended in-port period), comparisons were made between performances on the initial and final day and night landings of an at-sea period. The first landings of a line period were made following periods of from one to three weeks without any flying or carrier landing practice.

Figures 14 and 15 show the overall comparison of performance at the beginning and end of a line period for the entire sample over the duration of the cruise. Differences in performance levels as measured by both LPS and boarding rate are evident and similar for both day and night landings. The same results were noted for all three squadrons when taken separately. Four out of eight day comparisons and five of eight night comparisons show a marked performance decrement after an in-port period of no flying. The decrement trend is slightly larger at night and is thought to be related to

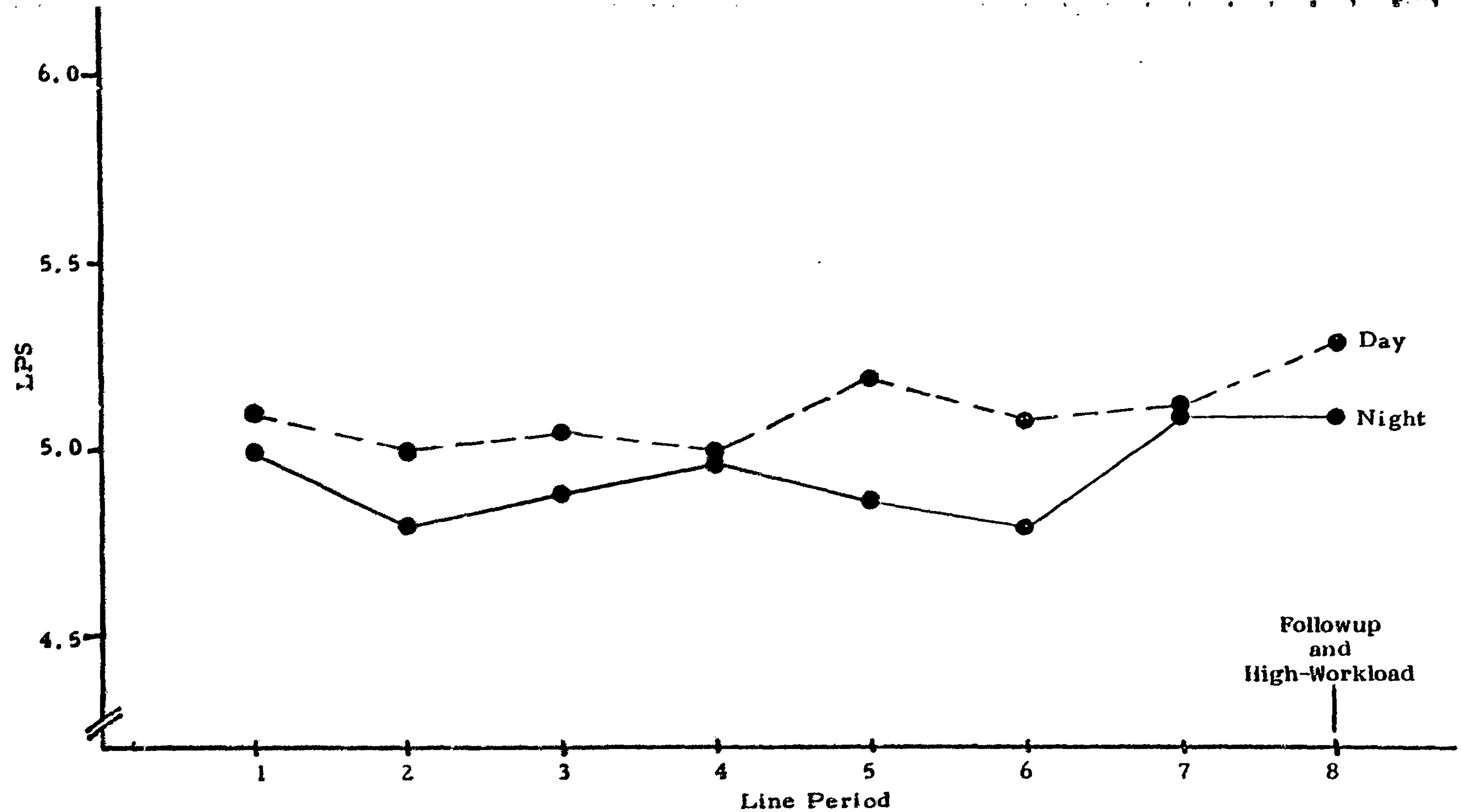

Figure 12. Day and night landing performance scores for three VA squadrons during a Mediterranean deployment.

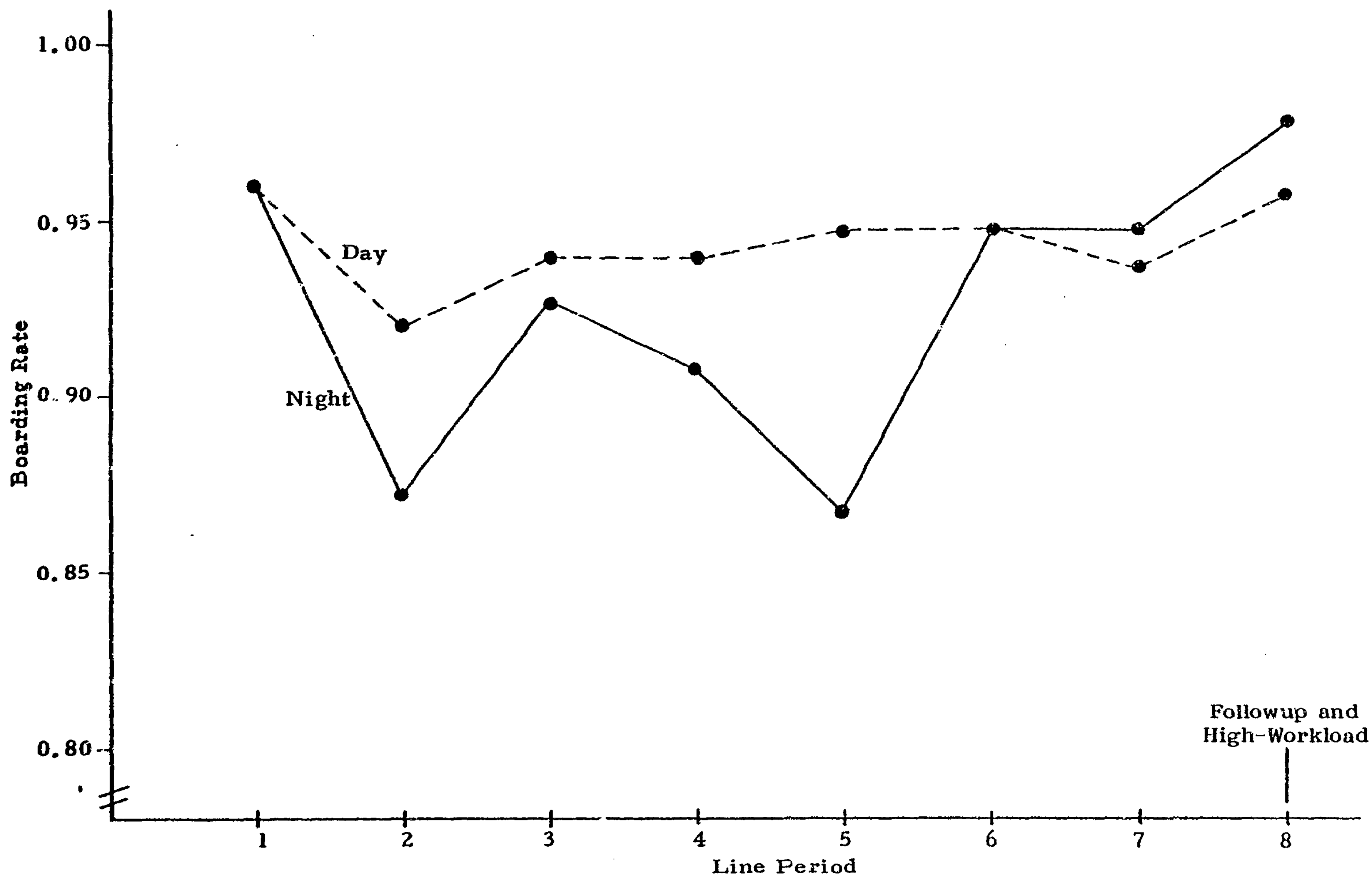

Figure 13. Boarding rate for all VA squadrons by line period -- day and night.

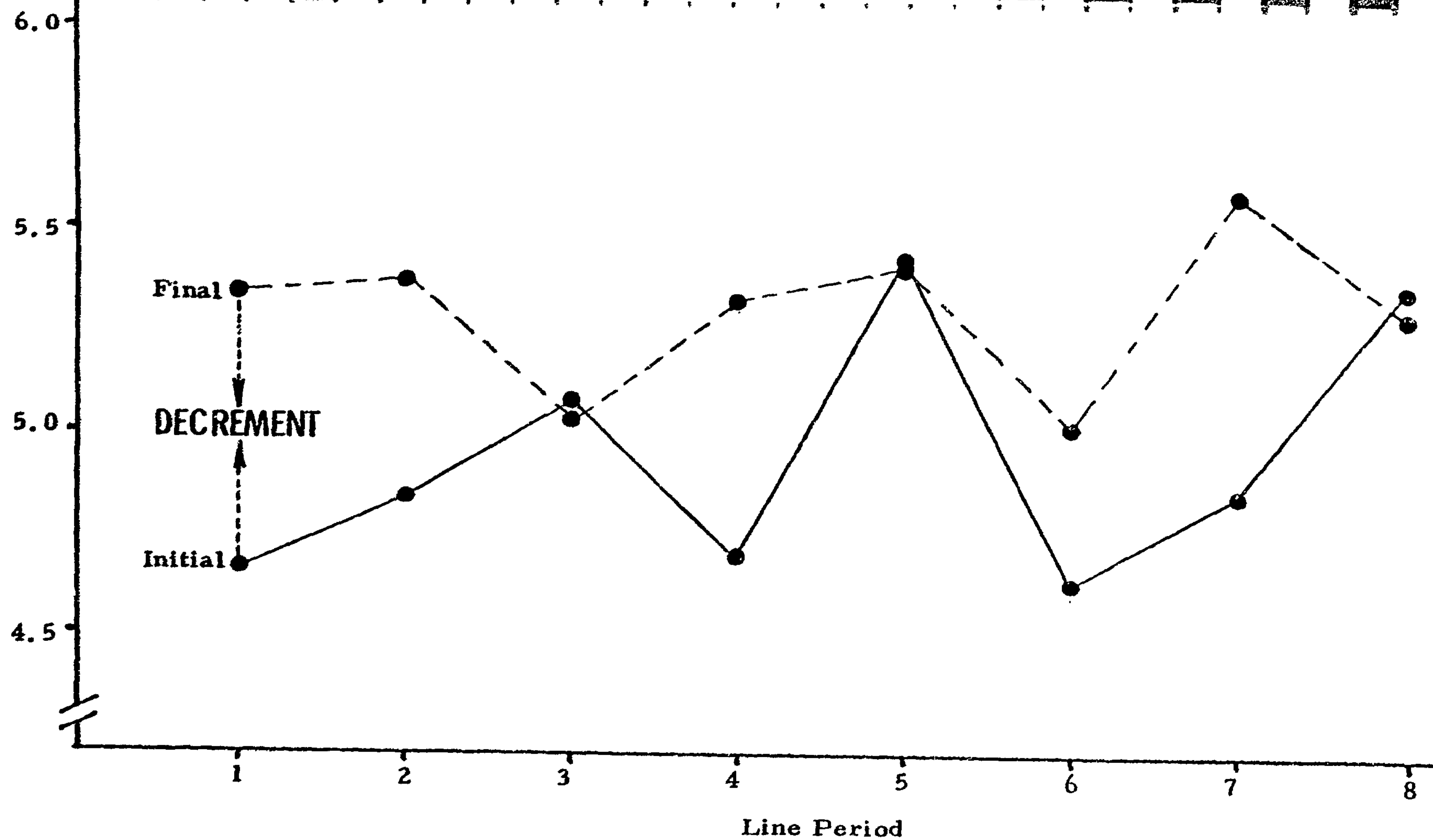

Figure 14. Night landing performance for all VA squadrons -- initial vs final landing of line period.

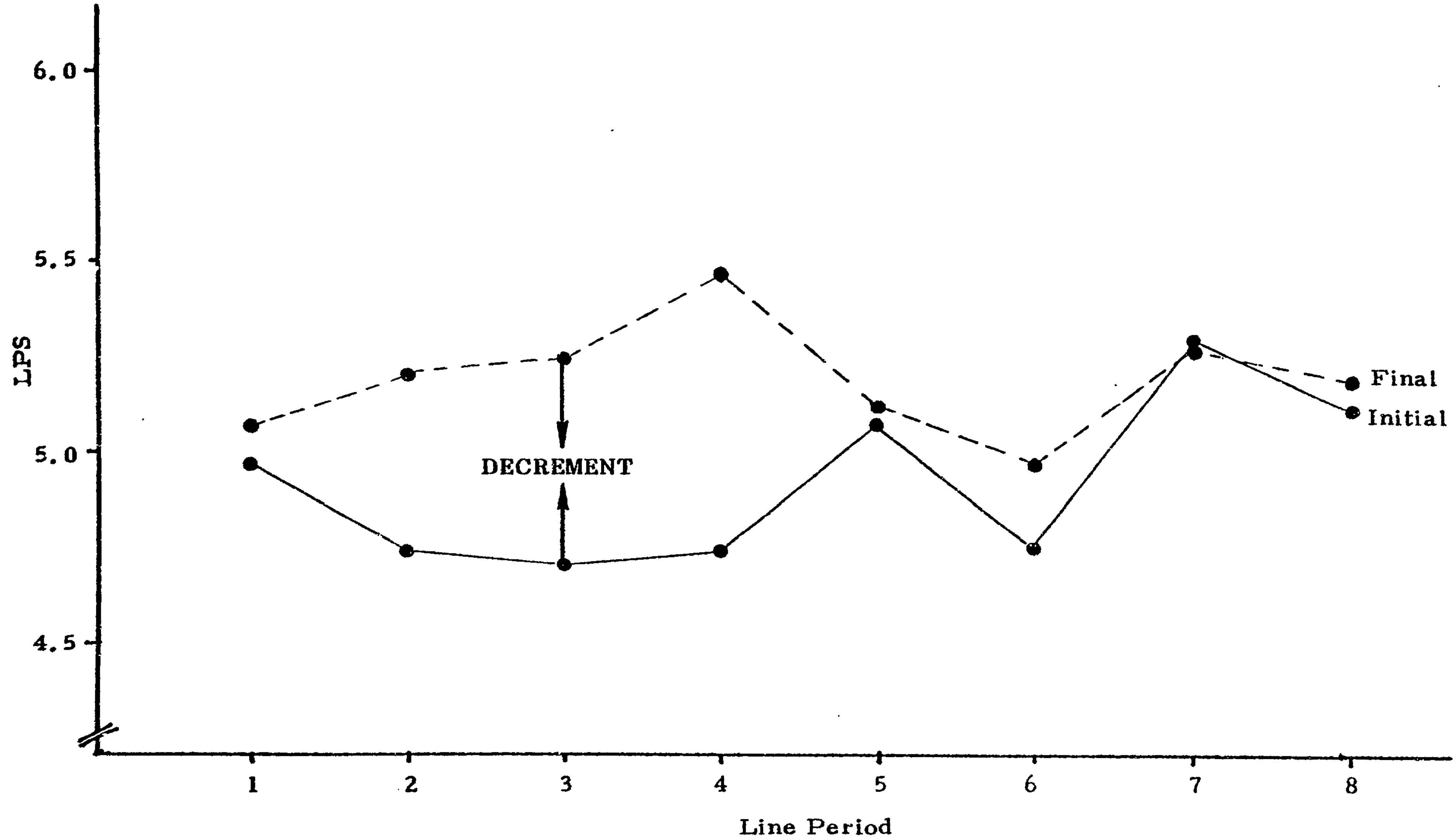

Figure 15. Day landing performance scores for all VA squadrons -- initial vs final landing of line period.

the more difficult aspects of night landing and a larger decay of landing skill due to inactivity. These results may have implications for a portable shipboard visual landing trainer now under development at NAVTRAEQUIPCEN, Orlando, Florida. Such noted performance decrement could be alleviated by visual trainer periods for certain pilots whose landing skills had decayed over time due to inactivity.

Landing Performance Summary. A basic conclusion drawn from these data is that carrier landing proficiency, as demonstrated by the study sample group, is remarkably high, both when measured using the Landing Performance Score and when evaluated from the standpoint of boarding rate. These results run contrary to expectations. The schedule and tempo of carrier flight operations in the deployment sample represent a dramatic reduction in comparison to Vietnam-era deployments. Pilots were allotted fewer flight hours, and made fewer carrier landings over the course of this cruise than were typical during combat operations. Consequently, lower landing performance scores and boarding rates were expected. What occurred were higher scores, boarding rates and overall landing proficiency both day and night. One possible explanation may be in the contrast between peacetime and combat carrier operations. Another possible reason may be the introduction of the night carrier landing trainer (NCLT) into the pilot training program. Whatever the cause, the landing proficiency was outstanding. And because of the consistently high performance, very little performance variation was observed. This lack of variability prevented any meaningful analysis of the effects of temporal variables on performance. Consistently high performance and little variability coupled with stable work levels and sleep activity limited the use of any comparative analyses.

Landing performance levels showed a general improving trend over the course of the deployment. This trend is reflected in comparisons between overall performance levels and scores for the Followup study period, which was the last at-sea period of the cruise.

Pilot landings made at the beginning of a particular at-sea period were markedly poorer than those made at the end of a period, after recent practice.

This difference held true for both day and night landings. Performance decrements were especially notable at night after in-port periods of no flight activity. The use of a carrier landing refresher trainer for use aboard ship to alleviate just such performance decrements appears to be a potential solution to this problem area.

CQ Sample

Pilot and LSO daily activities and performance data were obtained and analyzed for FCLP and CQ periods of training. These data are presented first for FCLP and CQ comparing RPs vs LSOs, and second, by comparing RPs for FCLP vs CQ and LSOs for FCLP vs CQ.

Daily Activity and Sleep During Field Training (FCLP Period). Daily activity was divided into seven mutually exclusive categories. Subjects reported the amounts of time spent on each activity in the course of each 24-hour day. Average activity allocations for RPs and LSOs during FCLP workup periods are listed in Table 8, and further illustrated in Table 9 which summarizes the breakdown of daily activities into simple work/nonwork allocation. Figure 16 illustrates this summary. As can be seen, LSOs work 43 percent more hours per day and get 26 percent less sleep per day than RPs. This high-workload condition is attributable to several interrelated factors. First, only two LSOs are normally in charge of a training class that can number up to ten or more. Daily training sessions (lectures, simulator flights) are often conducted on a one-to-one basis, and diagnostic debriefs of individual landing problems are conducted immediately after each field landing practice flight. Thus, LSOs must spend a great deal of each day in training, lecturing, and debriefing individual pilots. This situation is compounded by the fact that each LSO also has at least one area of responsibility within the squadron administrative or operations structure (RPs have no squadron administrative duties). This means that each LSO is required to fulfill his squadron administrative tasks in addition to his training duties. The net effect of these responsibilities is seen in the 12-hour workday for an LSO conducting carrier qualifications training classes.

TABLE 8. RP AND LSO DAILY ACTIVITY ALLOCATION(HOURS PER DAY) DURING FCLP PERIOD.

Group	N (man-days)	Flying/ Waving	Pre/Post Flight	Sqd Work	Eat	Sleep	Exer	Other Nonwork
RPs	132	2.1	4.3	2.0	1.3	8.9	0.3	5.1
LSOs	28	4.1	2.2	5.7	1.3	6.6	0.1	3.9

TABLE 9. WORK/NONWORK ALLOCATION (HOURS PER DAY) - FCLP

Group	N (man-days)	Work	Nonwork
RPs	132	8.4	15.6
LSOs	28	12.0	12.0

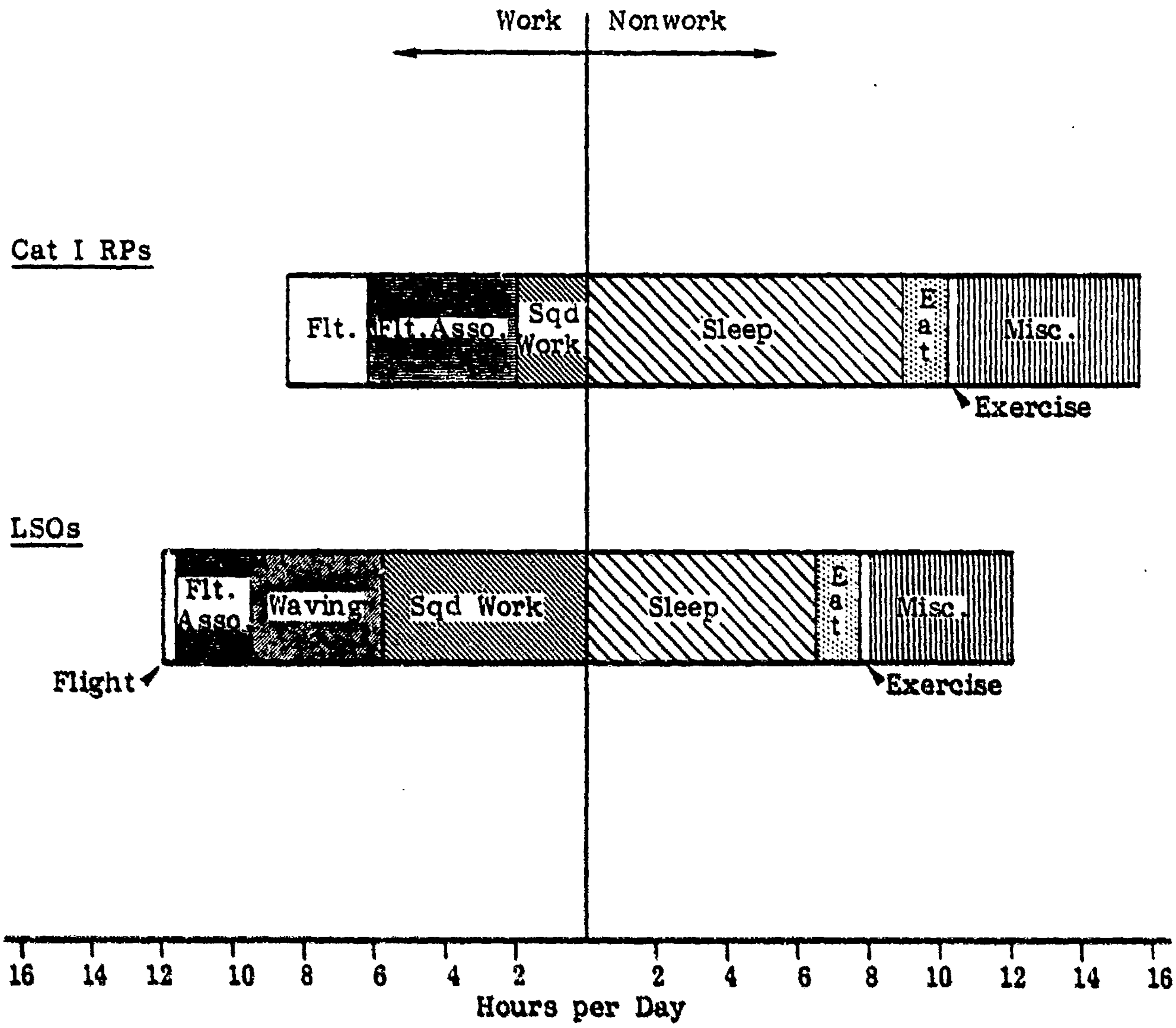

Figure 16. Daily Work/Nonwork Allocation (FCLP) — LSOs and RPs.

Figure 17 depicts the sleep patterns for RPs and LSOs during the FCLP period. Vertical dimension on these charts indicates the proportion of that group which was asleep at a given time of day over the entire reporting period. As can be seen, both groups tend to go to sleep late (50 percent asleep by 0100), but the LSOs tend to rise early (50 percent awake by 0700), while the RPs slept longer (50 percent awake by 1000). Since LSOs have more responsibilities and duties, and are required to be on hand for all individual simulator training sessions, their work schedule is longer than RPs.

Further information on the sleep patterns of the two groups, comparing distributions of the total amount of sleep reported in a 24-hour period, and sleep episode duration, respectively, are found in the Appendix. Both figures show that LSOs tend toward shorter sleep episodes and less overall sleep daily.

Some idea of the quality of sleep for each group was given by the daily responses to two questions:

- "How much trouble did you have getting to sleep?" (when retiring)
- "How well rested do you feel?" (after rising)

Responses to these questions would be indicators of whether or not sleep could be classed as "recuperative" or "non-recuperative." Figures showing the relative frequencies of responses to these two questions, compared for RPs and LSOs, are in Appendix B. Although both groups reported "no trouble" or only "slight trouble" in getting to sleep more than 80 percent of the time, LSOs reported feeling only "slightly" or "not at all" rested 50 percent of the time. Only 14 percent of the time did RPs report non-recuperative sleep.

Daily Activity and Sleep During CQ. Culmination of the carrier landing training phase for RPs comes when the pilots must demonstrate their ability to landing on a carrier at sea under day and night conditions. This CQ period typically covers three or four days to a week at most.

Activity breakdowns for LSOs and RPs on CQ are listed in Table 10 and 11. Figure 18 illustrates this breakdown. The category of Squadron Work shows no entries during this period dedicated to training qualification. Again, it can

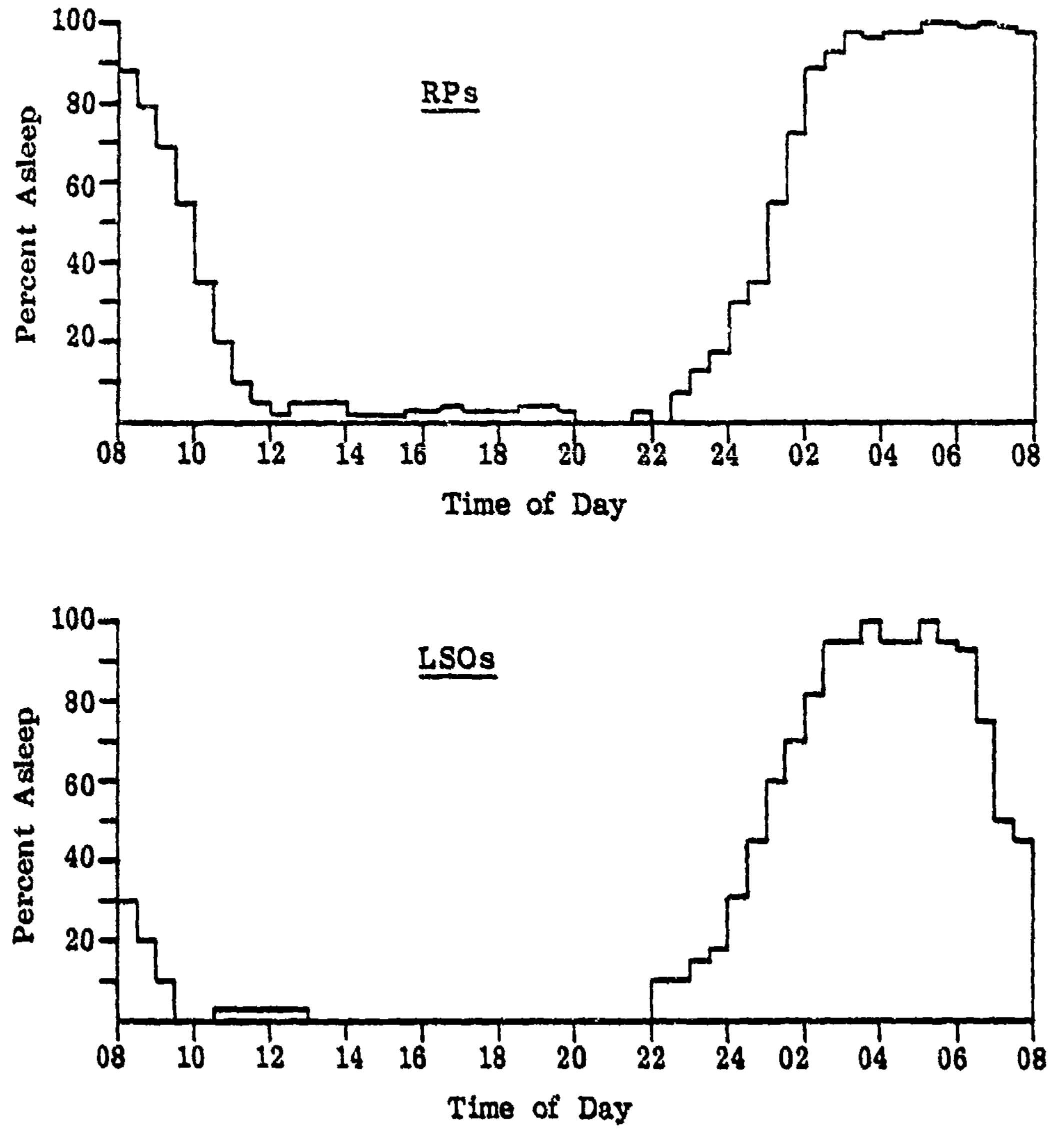

Figure 17. Sleep Patterns During FCLP Workup.

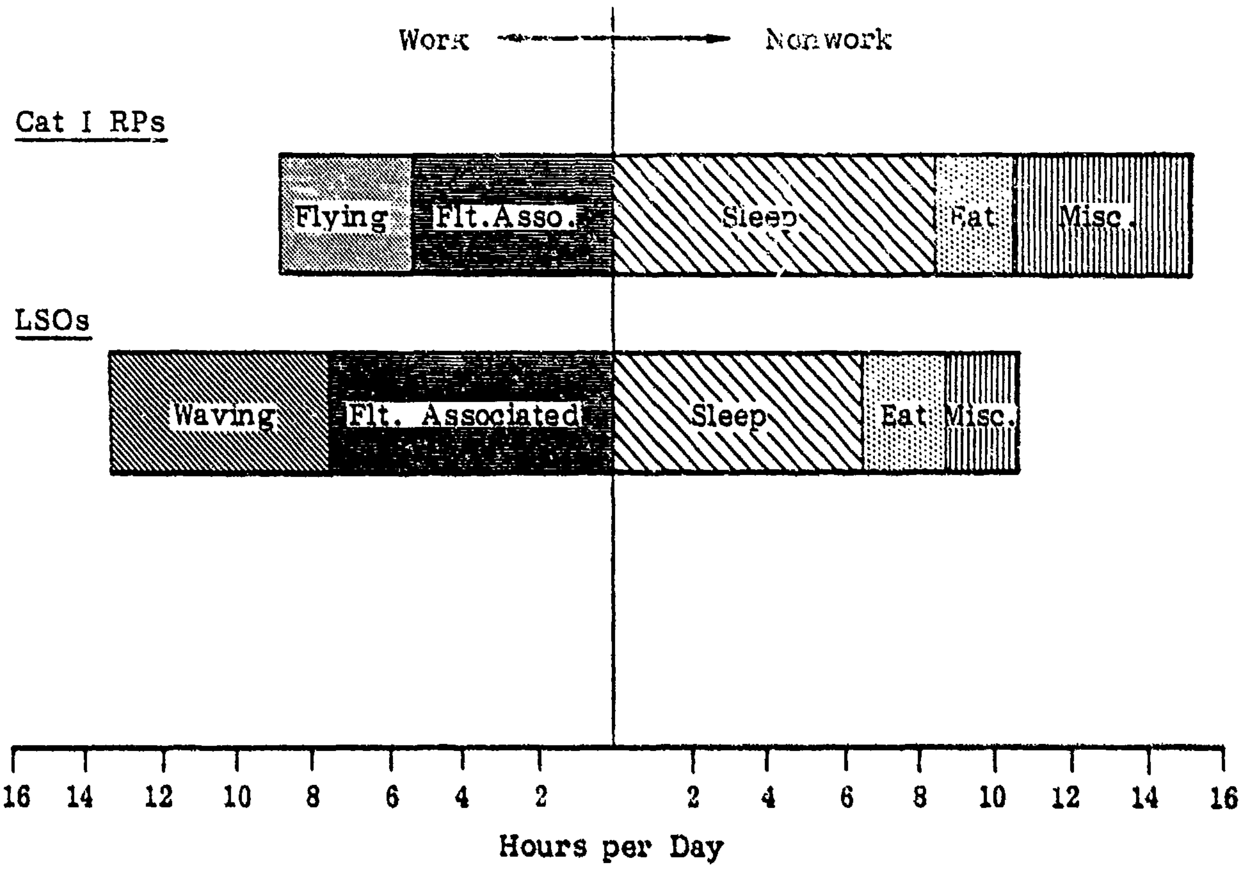

Figure 18. Daily Work/Nonwork Allocation (Shipboard CQ) -- LSOs and RPs.

TABLE 10. DAILY ACTIVITY (HOURS PER DAY) - CQ PERIOD

Group	N (man-days)	Flying/ Waving	Pre/Post Flight	Sqd Work	Eat	Sleep	Exer	Nonwork
RPs	36	3.7	5.2	-0-	2.2	8.3	-0-	4.8
LSOs	8	5.8	7.5	-0-	2.2	6.6	-0-	1.9

TABLE 11. DAILY WORK/NONWORK ALLOCATION (HOURS PER DAY) - CQ

Group	N (man-days)	Work	Nonwork
RPs	36	8.9	15.1
LSOs	8	13.3	10.7

be seen that the LSOs allocate a substantial portion of their day to post-flight debrief of RP landing trends and difficulties. LSOs work 49 percent more hours and sleep 20 percent fewer hours than RPs during CQ. Extended hours are also devoted to observing and controlling RP qualification landings (Waving). Work/nonwork allocation shows that LSO workload is 13.3 hours per day during CQ compared with about nine hours for RPs.

Sleep levels for RPs dropped slightly during CQ, but LSOs continued to report the same daily amount of sleep. The most notable factor in sleep activity levels for RPs and LSOs during CQ was the occurrence of nap activity during the daytime. Responses to questions about the quality of sleep were not sufficient to construct any reliable distribution of answers.

Replacement Pilot Activity and Sleep During FCLP and CQ. Since the Carrier Qualification (CQ) phase of training comes immediately after several weeks of intensive activity, and in itself represents an intensive, stressful situation for the RP, comparisons of activities and sleep patterns between the two phases might point up any potential sources of additional stress. Although CQ is relatively short in length, the combination of many factors (including shifts of disruption of daily routine or sleep habits) may be a factor in CQ performance. Daily activity distributions for RPs during FCLP and CQ are shown in Table 12.

TABLE 12. DAILY ACTIVITY (HOURS PER DAY) FOR RPs - FCLP vs CQ

Phase	N (man-days)	Flying	Pre/Post Flight	Sqd Work	Eat	Sleep	Exer	Nonwork
FCLP	132	2.1	4.3	2.0	1.3	8.9	0.3	5.1
CQ	36	3.7	5.2	-0-	2.2	8.3	-0-	4.8

Work/Nonwork allocation is shown in Table 13. Only a slight shift (to one-half hour more work per day) is evident, but a sharp rise in the number of hours of flying can be noted. When flight hours and pre- or post-flight time are combined, the CQ period shows a total of 8.9 hours per day devoted to flight-associated tasks--an increase of nearly 40 percent over FCLP levels. Since Squadron Work includes lectures and simulator training sessions for RPs, the fact that no time was spent on these activities during CQ was expected.

TABLE 13. WORK/NONWORK ALLOCATION (HOURS PER DAY) FOR RPs - FCLP vs CQ

Phase	N (man-days)	Work	Nonwork
FCLP	132	8.4	15.6
CQ	36	8.9	15.1

Total sleep per day dropped slightly from FCLP levels during CQ, but the loss could not be considered appreciable. Sleep activity patterns over the two phases differed only slightly in that there was a general trend to retiring and rising earlier (50 percent asleep by 0100 during FCLP, while the same proportion reported asleep by 2330 during CQ; likewise half were awake by 0800 in CQ as opposed to 1000 for FCLP).

Landing Signal Officer Activity and Sleep During FCLP and CQ. Data obtained for LSOs during FCLP showed a high proportion of hours per day spent on work (12.0 hrs) plus a relatively low daily sleep total (6.6 hrs). Since the LSOs primary responsibility during CQ is to act as quality and safety monitors during carrier landings, activity and sleep patterns both preceding and during CQ could be critical to maintain alertness. Further, radical shifts in these patterns during CQ could serve to aggravate the physiological and psychological stresses inherent in the critical tasks performed by LSOs.

Table 14 compares daily activities for LSOs during FCLP and CQ phases. Table 15 shows the simplified division of work/nonwork allocation for the two periods.

TABLE 14. DAILY ACTIVITY (HOURS PER DAY) FOR LSOs - FCLP vs CQ

Phase	N (man-days)	Waving	Pre/Post Flight	Sqd Work	Eat	Sleep	Exer	Nonwork
FCLP	28	4.1	2.2	5.7	1.3	6.6	0.1	3.9
CQ	8	5.8	7.5	-0-	2.2	6.6	-0-	1.9

TABLE 15. DAILY WORK/NONWORK ALLOCATION FOR LSOs - FCLP vs CQ

Phase	N (man-days)	Work	Nonwork
FCLP	28	12.0	12.0
CQ	8	13.3	10.7

LSO daily work levels, already high during the FCLP phase, increased over the CQ period by more than ten percent. As expected, Squadron Work (lectures, simulator training, and administrative duties) dropped to zero during CQ, but the dramatic increase in Pre/Post-flight work (briefings and critques of landings) and in time spent on the LSO platform (Waving) more than made up for this shift.

Sleep levels remained constant during CQ, with only slight differences in sleep patterns. Rising times tended to be slightly earlier during CQ, but the loss in nightly sleep was compensated for by increased nap activity during afternoon hours.

Comparison of Daily Activity and Sleep Patterns with other Navy Groups

Activity and sleep patterns found in the CQ study may stand comparison to patterns noted in other similar studies of Navy personnel. For example, in the deployment sample, daily activity distributions and sleep habits for a sample of 21 Naval aviators involved with sustained flight operations on an overseas carrier deployment were described and compared with ship crew personnel. Sleep activity data for Navy shore personnel are also available for comparison.

Carrier Qualification vs Fleet Squadron at Sea. Table 16 shows daily activity breakdowns for both RPs and LSOs during CQ and for VA squadron pilots at sea. Table 17 simplifies these data into work/nonwork categories. Figure 19 provides a graphical view of the comparison. It is readily apparent that the daily activity and work/nonwork allocations of the LSOs during CQ most closely resemble those of pilots involved in sustained air operations at sea. Several important differences do merit note. LSOs devote more time to work, despite the fact that no time is allotted to Squadron Work (administrative tasks). Further, LSOs report less total sleep over a 24-hour period.

Figure 20 compares sleep activity patterns for LSOs to those of the VA pilots. Longer sleep totals for the VA sample are reflected in the earlier retiring and later rising times. LSOs also show greater tendency toward napping as a means of supplementing short sleep hours at night.

TABLE 16. DAILY ACTIVITY (HOURS PER DAY) COMPARISON.

Group	N (man-days)	Flying/ Waving	Pre/Post Flight	Sqd Work	Eat	Sleep	Exer	Nonwork
RPs (CQ)	36	3.7	5.2	-0-	2.2	8.3	-0-	4.8
LSOs (CQ)	8	5.8	7.5	-0-	2.2	6.6	-0-	1.9
VA Pilots	63	3.7	3.6	5.4	1.3	8.0	0.2	1.7

TABLE 17. WORK/NONWORK COMPARISON.

Group	N (man-days)	Work	Nonwork
RPs (CQ)	36	8.9	15.1
LSOs (CQ)	8	13.3	10.7
VA Pilots	63	12.7	11.3

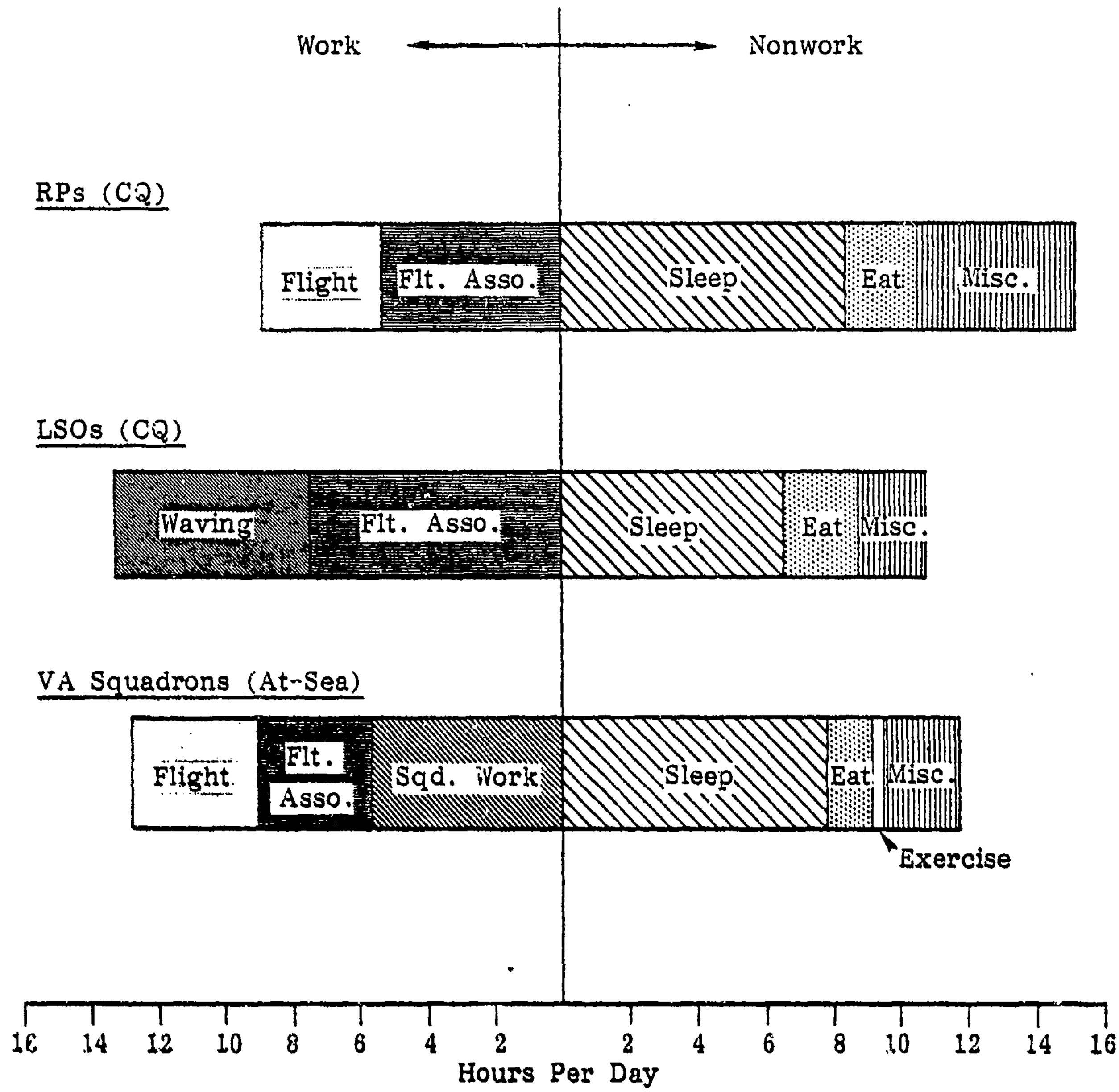

Figure 19. Daily Work/Nonwork Allocation (RPs and LSOs during CQ vs VA squadron aviators during Mediterranean deployment).

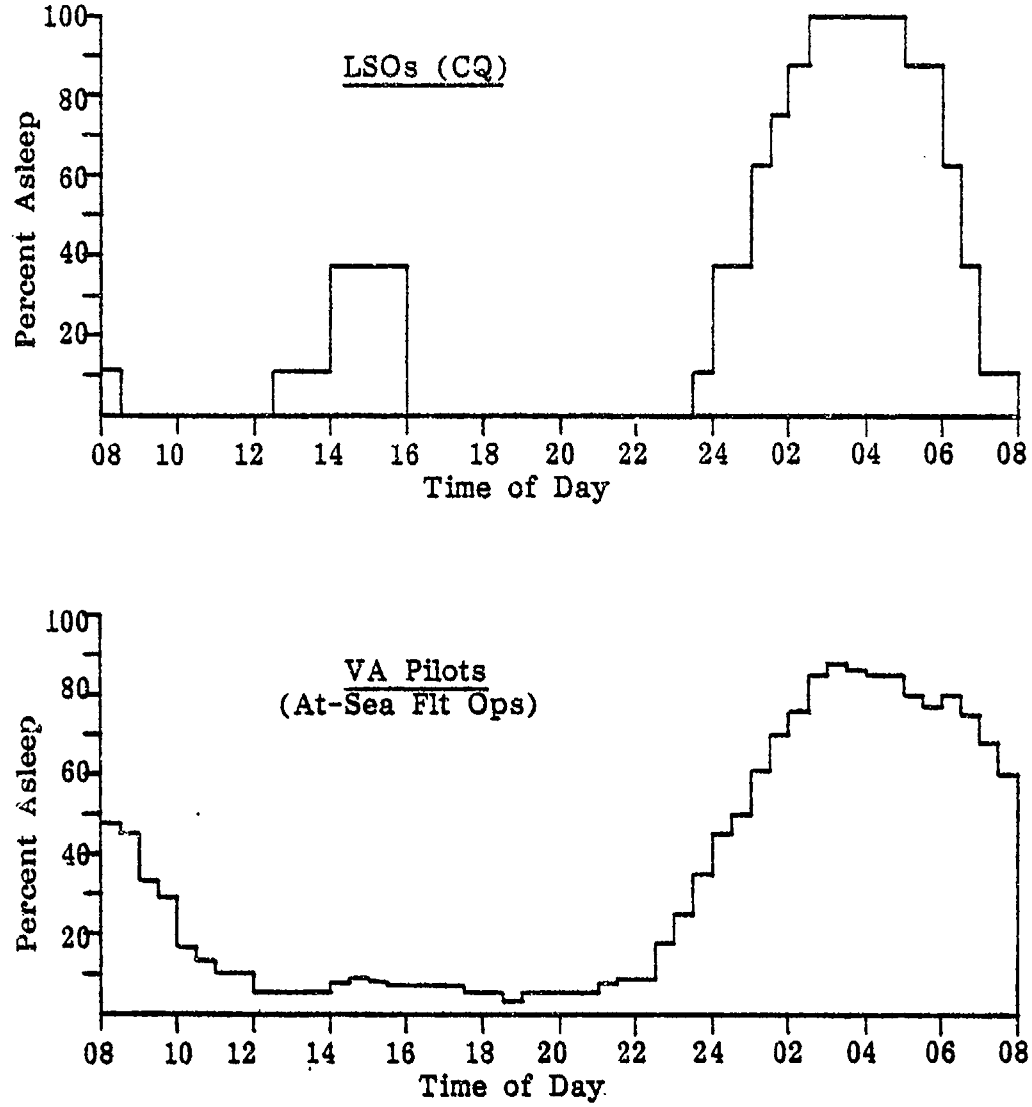

Figure 20. Sleep Activity -- LSOs vs Pilots on Sustained At-Sea Flight Operations.

Sleep Patterns During FCLP vs Navy Shore Station Personnel. Previous research (13) looked at the sleep activity and habits of a number of groups of subjects within the Navy community. Among these was a sample of individuals assigned to a Navy shore establishment whose daily routine was close to what might be considered a "normal" routine for civilian groups. That is, the shore station personnel kept more or less standard working and nonworking hours, and most significantly acquired almost all daily sleep in a single "night's sleep" episode ending in the early morning.

An apt comparison might be made between the sleep habits of shore station personnel and those of RPs and LSOs during FCLP training, since duty with a Fleet Readiness Squadron is considered as shore station duty by the Navy.

Three figures in Appendix B compare sleep habits of RPs and LSOs during CQ with those of shore station Navy personnel along the dimensions of Total Sleep (in 24 hours), Sleep Episode Duration, and Sleep Activity, respectively.

Total sleep distribution for LSOs during FCLP was more variable than the shore station group pattern, and also showed lower daily totals of sleep. RPs, despite undergoing extensive training, actually averaged more sleep per day than shore-based personnel. Distributions of Sleep Episode Duration showed LSO sleep to be more fragmented, with shorter periods of uninterrupted sleep than either RP or shore personnel. In general, shore personnel sleep episodes tended to be much more consistent than those of the RP or LSO groups. Patterns of sleep activity for the three groups again point up the longer RP sleeping hours and the consistency of the shore personnel sleep habits.

CQ Sample Summary. A comparative summary of CQ temporal variables indicate that LSOs work longer hours and sleep less than RPs during both FCLP and CQ. LSOs not only allocated more hours per day to work (12.0 vs 8.4) and reported less sleep (6.6 hrs vs 8.9 hrs) than RPs during the FCLP portion of the carrier qualification training cycle, but also reported a higher incidence of non-recuperative sleep in this period. During CQ LSOs spent 13.3 hours out of every day on work, as opposed to a total of 8.9 hours for RPs. LSOs again slept less (6.6 hrs) than RPs (8.3 hrs) in CQ. Sleep patterns reported over CQ did not show any major disruption of previously established patterns.

Daily activity levels for Replacement Pilots showed only slight changes from FCLP to CQ, and those differences were predictable. RP flying and flight-associated tasks increased to account for all daily work activities, but overall hours spent on work increased only slightly. RP sleep levels decreased slightly during CQ, and sleep activity shifted from FCLP patterns to earlier hours for retiring and rising. The effect of this shift is not readily discernable, but it may be important to note that the shift in retiring/rising times was from somewhat late hours (0100 - 1000) during FCLP to what could be considered to be a more "normal" cycle (2330 - 0800) for CQ.

Daily work activity levels for LSOs increased during CQ by more than 10 percent over FCLP levels. All work during CQ was associated directly with LSO duties as quality and safety monitors during carrier landings. Total daily sleep did not show any change during CQ, but a slight pattern shift to earlier rising and more afternoon naps was noted.

Finally, LSO daily activity levels during CQ, including work/nonwork allocation and sleep, most closely approximate the patterns found for VA squadron pilots involved in sustained flight operations at sea. The data imply, however, that LSOs conducting carrier landing training groups work longer hours, and sleep less, than pilots involved in sustained at-sea operations. Ironically, LSO CQ training duty, it should be noted, is regarded as shore duty by the Navy. When sleep habits during FCLP were compared to those of shore station personnel, only the RP sleep patterns appeared to be similar to shore personnel, with one exception; RPs appeared to be averaging slightly more hours per day sleeping than shore personnel.

DISCUSSION

A study of pilot temporal indicators of performance effectiveness is not without hazards. In this instance the lack of significant performance variation during the deployment sample and the use of novice pilots just acquiring the skills associated with carrier landing precluded the direct assessment of how temporal variables may influence pilot landing performance.

Several results of the study, however, are noteworthy. Certainly one of the more significant aspects was the demonstration that pilot daily activity and sleep data can, indeed, be collected concurrently with performance data in an operational setting without interferring with that behavior. That result should stimulate and encourage further research in the area. A second result considered to be noteworthy was the remarkably high carrier landing performance that occurred during the Mediterranean deployment. Despite predictions and hypotheses that landing performance might deteriorate due to less frequent flight activity, the three VA squadrons achieved the highest day and night landing performance yet recorded. The combined attack pilot proficiency profile was at the 95th percentile by night, and the 92nd percentile by day--for the entire cruise.

Other results that may prove useful for medical and performance effectiveness planning purposes are the pilot workload data. Attack pilots consistently worked 12-hour days during deployment, whether flying or not. Sleep activity was notable only for the incidence of recuperative naps during operational flight periods. The survey of LSO workload and sleep activity may also be of interest. LSO workload, while training novice pilots, most closely resembled that of attack aviators during sustained operations at sea. LSOs averaged over 13 hours per day during the CQ training phase and slept just over six hours per night. The long-term effects of such work schedules are important for training effectiveness as well as LSO retention. These workload data support the longstanding LSO notion that FRS duty is more like sea duty than shore duty, and indicate that LSOs, indeed, work long, tiring hours in the course of preparing RPs for CQ.

The aspect of performance that was somewhat predictable was that of performance decrement after in-port periods. Previous work had found indications of night performance decrement after in-port periods of no flying, but usually day landing performance after such periods showed little decrement. In this study, both day and night performance showed some dropoff in overall proficiency as measured by the LPS and boarding rate. Due to the unusually high overall day landing performance, this may be an artifact for daytime landings but probably not for nighttime landings. The nature of night landing skill acquisition and retention supports the decrement notion after inactivity and should lend additional support for the continued development of the NAVTRAEQUIPCEN program of a portable shipboard night landing visual trainer.

It is hoped that the search for easily applied techniques to assess pilot flight readiness in stressful environments has not ended with this report. The notion that a pilot can be subjected to a medical readiness check in the same fashion that aircraft are now checked for flight readiness still prevails. While this research incurred some formidable obstacles in its completion, some of those obstacles were not unexpected and were considered part of the nature of the process. In the course of the study, some innovative techniques for analyzing landing performance and temporal variables were followed. One such technique concludes this research and is presented in Appendix C to indicate potential trends for future study in this area. In the example, individual pilot performance effects, as opposed to group effects, are examined to determine whether pilot performance decrement can be related to temporal variables on an individual basis.

Johnson and Naitoh (12) pose perhaps the most interesting questions regarding the operational consequences of sleep loss. They recommend, as one measure of aircrew recoverability, the time required to stabilize sleep as a criterion of recovery. In the case of deployed attack aviators, the extended flight schedules produced average work days of 12 hours but little sleep loss or instability, regardless of operational tempo. The long-term effects of 12 hour workdays do not seem to be related to performance decrement in this study. While LSOs worked even longer periods of time per day, they did not fly, so no measures of performance for them are available. However, 13-hour work days are excessive over long periods of time and the physiological cost of continued sleep loss for LSOs as opposed to other aircrew members should be determined. At present, LSOs are departing the Navy in record numbers and long work schedules without adequate recovery, compensation, or recognition may contribute to this exodus.

The long-term effects of physiological costs related to LSO workload and sleep, while not the primary goal of this research, need to be determined, expecially when LSOs are in flight status during operational cruises.

In conclusion, this study has addressed some of the research suggestions posed by Woodward and Nelson (10). Their caveat should not be unheeded.

> "We are still a long way from having the answers to all the questions on the effects of sleep loss (or work-rest schedules) on performance."

The performance research under operationally defined stress environments did not completely answer any or all the questions thought to be important in this area of study. What was accomplished was the compilation and analysis of additional information about sleep loss and work-rest schedule effects on groups and individuals performing in routine Navy operations. We hope it will ultimately provoke more questions and answers.

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APPENDIX A

CARRIER DEPLOYMENT SAMPLE

- Daily Activity and Sleep Log
- Landing Performance Scores for Attack Aviators
- Landing Performance Scores
- Boarding Rates for Followup Sample
- Night Boarding Rate Decrement
- Day Boarding Rate Decrement
- Day and Night LPS for VA Squadrons

DAILY ACTIVITY/MOOD SHEET (7/78)

Name: Any Pilot

Subject No.: 0001

Date and Time this log was filled in: ____/____/____ : : Now

Date covered in this log: ____/____/____

INSTRUCTIONS

Fill out this sheet each morning for the previous day's activities. The activity chart is divided into half-hour segments. Fill in each segment with the appropriate activity code taken from the table below. Be sure that each and every time block is covered by some activity. You may draw lines from the start to end of a code to indicate continuous activity.

EXAMPLE:

3L	—	—	—	—	—	—	3L	2	2	1	—	1	2	4	4	6	5	7	—	—	—	—	7
08		09		10		11		12		13		14		15		16		17		18		19	

DAYTIME

3	—	—	—	—	—	—	3	4	3	—	—	—	—	—	—	3	7	4	3	—	—	—	3
08		09		10		11		12		13		14		15		16		17		18		19	

NIGHT TIME

3	—	—	3	7	7	6	7	—	7	5	—	—	—	—	—	—	—	—	—	5	7	4	4
20		21		22		23		24		01		02		03		04		05		06		07	

ACTIVITY CODES:

1. Flying (engine start to shut-down)
2. Pre/Post Flight (including brief/debrief)
3. Squadron Work (3L=lectures/ 3T=trainers/3S=study)
4. Eating
5. Sleeping and Naps
6. Exercise
7. All other Non-work Activity

How much trouble did you have going to sleep last night?

☐ None ☐ Slight ☐ Moderate ☐ Considerable

How well rested do you feel?

☐ Well Rested ☐ Moderately Rested ☐ Slightly Rested ☐ Not at all Rested

Figure A-1. Daily Activity Log.

- - - - - - - - - - - - - - - - - - - -

MOOD QUESTIONNAIRE

Below is a list of words describing moods and feelings. Indicate how each word applies to how you feel NOW by making a heavy dark mark between the appropriate lines using the scale listed below:

1 = Not at all 2 = Somewhat or slightly 3 = Mostly or generally

	1	2	3
1. LOW			
2. LIVELY			
3. IRRITATED			
4. CONTENTED			
5. ACTIVE			
6. RESTFUL			
7. IMPATIENT			
8. MEAN			
9. WEARY			
10. ANXIOUS			

	1	2	3
11. CALM			
12. BLUE			
13. BURNED UP			
14. STEADY			
15. AFRAID			
16. HAPPY			
17. MISERABLE			
18. ALARMED			
19. LAZY			
20. DROWSY			

	1	2	3
21. DOWNCAST			
22. PLEASED			
23. SATISFIED			
24. DEPRESSED			
25. ENERGETIC			
26. CHEERFUL			
27. UNEASY			
28. GROUCHY			
29. SLUGGISH			
30. VIGOROUS			

	1
31. ALERT	
32. ANNOYED	
33. SAD	
34. HOPELESS	
35. INSECURE	
36. JITTERY	
37. BORED	
38. TIRED	
39. GOOD	
40. ANGRY	

TABLE A-1. SUMMARY OF LANDING PERFORMANCE SCORES FOR ATTACK AVIATORS

DAY LANDINGS

Squadron	Overall N	Overall Mean	Overall s.d.	Followup N	Followup Mean	Followup s.d.	High-Workload N	High-Workload Mean	High-Workload s.d.
VA-34	417	5.01	1.18	53	5.31	0.82	22	5.34	0.79
VA-72	425	5.14	1.09	74	5.33	0.94	19	5.47	0.48
VA-46	464	5.11	1.12	81	5.31	1.02	28	5.25	0.90
All VA	1306	5.11	1.13	208	5.32	0.94	69	5.34	0.75

NIGHT LANDINGS

Squadron	Overall N	Overall Mean	Overall s.d.	Followup N	Followup Mean	Followup s.d.	High-Workload N	High-Workload Mean	High-Workload s.d.
VA-34	163	4.93	1.06	29	4.94	0.90	14	4.79	0.43
VA-72	153	5.02	1.12	18	5.36	0.71	10	5.30	0.71
VA-46	180	4.97	1.12	23	5.15	0.49	11	5.09	0.63
All VA	496	4.97	1.10	70	5.12	0.72	35	5.03	0.59

TABLE A-2. LANDING PERFORMANCE SCORES

	DAY			NIGHT		
Subject No.	No. of Landings	Boarding Rate	LPS Average	No. of Landings	Boarding Rate	LPS Average
VA-34 (A6E)						
136	50	0.90	4.84	23	0.87	4.87
146	55	0.98	4.78	22	0.82	4.45
148	77	0.82	4.68	24	0.88	4.81
138	64	0.98	5.26	17	0.88	4.50
140	49	0.98	5.37	25	1.00	5.42
141	60	0.98	5.14	14	1.00	4.96
143	54	0.96	5.10	24	0.96	4.98
139	64	0.88	4.51	21	0.81	4.24
147	58	0.88	4.97	23	0.96	5.09
149	57	0.91	5.09	25	1.00	5.06
142	58	0.91	4.78	25	0.84	4.54
144	53	0.98	5.23	24	0.88	4.79
145	55	0.96	5.18	20	1.00	5.28
Total	754	0.93	4.98	287	0.91	4.85
VA-46 (A7B)						
126	69	0.93	4.88	27	0.93	5.19
124	61	0.93	5.17	38	0.87	4.83
123	73	0.92	5.08	21	1.00	5.26
119	68	0.96	5.10	23	0.87	4.61
114	66	0.97	5.29	27	0.85	4.69
127	62	0.97	5.28	31	1.00	5.33
115	63	0.98	5.31	23	1.00	5.07
122	52	0.96	5.19	20	1.00	5.53
117	71	0.90	4.92	27	0.96	5.15
120	45	0.98	5.28	18	1.00	5.28
Unk.	63	0.95	5.19	27	0.93	4.98
Total	693	0.95	5.14	272	0.94	5.05
VA-72 (A7B)						
129	39	1.00	5.65	20	1.00	5.25
153	75	0.91	4.91	24	0.96	5.17
128	70	0.97	5.39	24	1.00	4.94
130	67	0.97	5.28	24	0.92	5.00
132	71	0.96	5.06	26	0.92	4.94
135	67	0.94	4.90	29	0.97	5.00
131	69	0.91	5.17	27	0.85	4.83
133	69	0.96	5.08	25	0.92	4.58
136	73	0.92	5.06	28	0.93	5.23
134	70	0.97	5.21	32	0.88	4.81
Total	670	0.96	5.15	259	0.93	4.97

TABLE A-3. BOARDING RATES (FOLLOWUP SAMPLE)

DAY LANDINGS

Squadron	Overall	Followup	High-Workload
VA-34	0.93	0.97	0.95
VA-72	0.96	0.95	1.00
VA-46	0.95	0.96	0.96
All VA	0.95	0.96	0.97

NIGHT LANDINGS

Squadron	Overall	Followup	High-Workload
VA-34	0.91	0.95	0.93
VA-72	0.94	1.00	1.00
VA-46	0.93	1.00	1.00
All VA	0.93	0.98	0.97

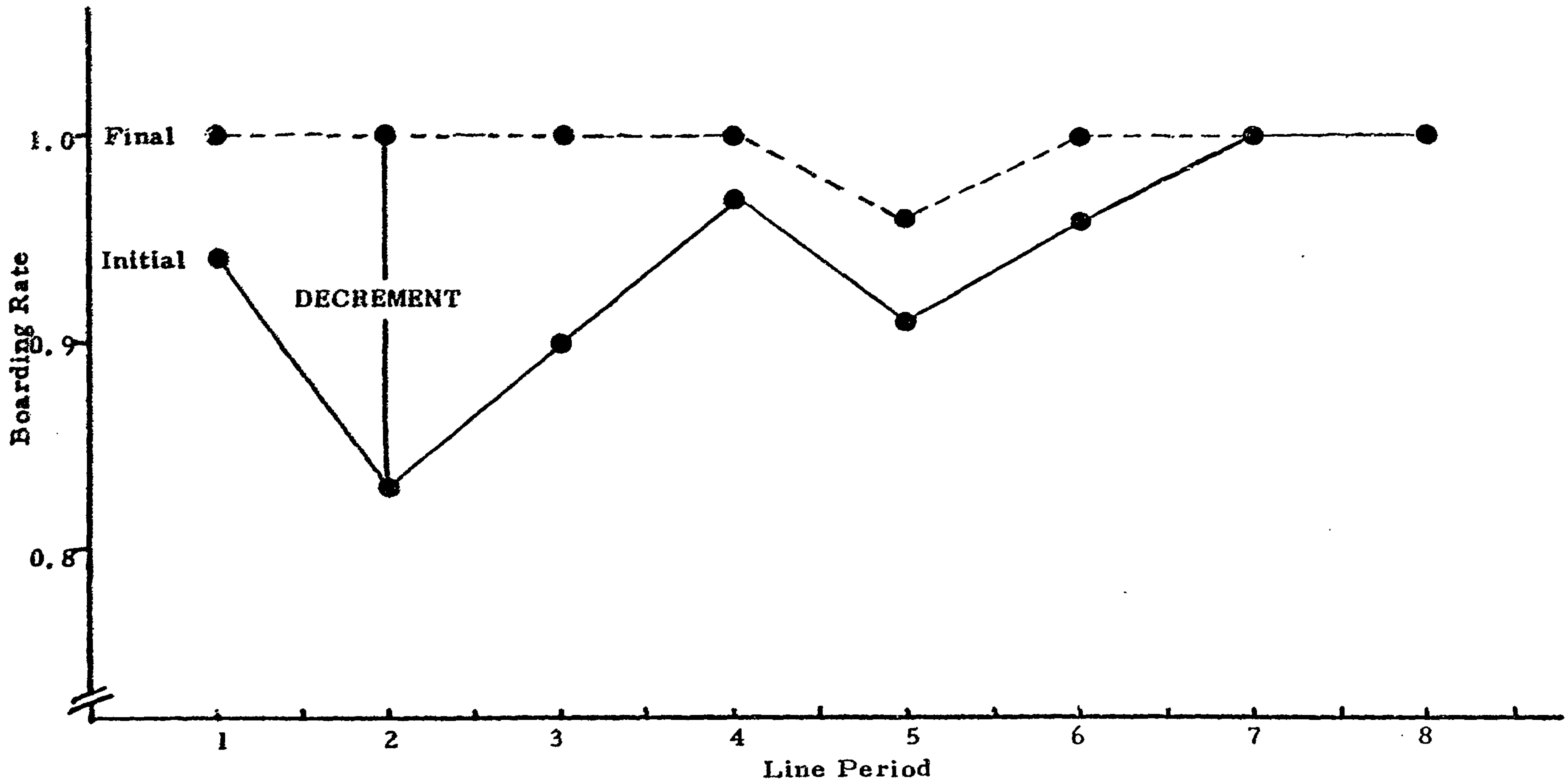


Figure A-2. Night boarding rate for all VA squadrons -- Beginning (initial landing) vs end of line period (final landing).

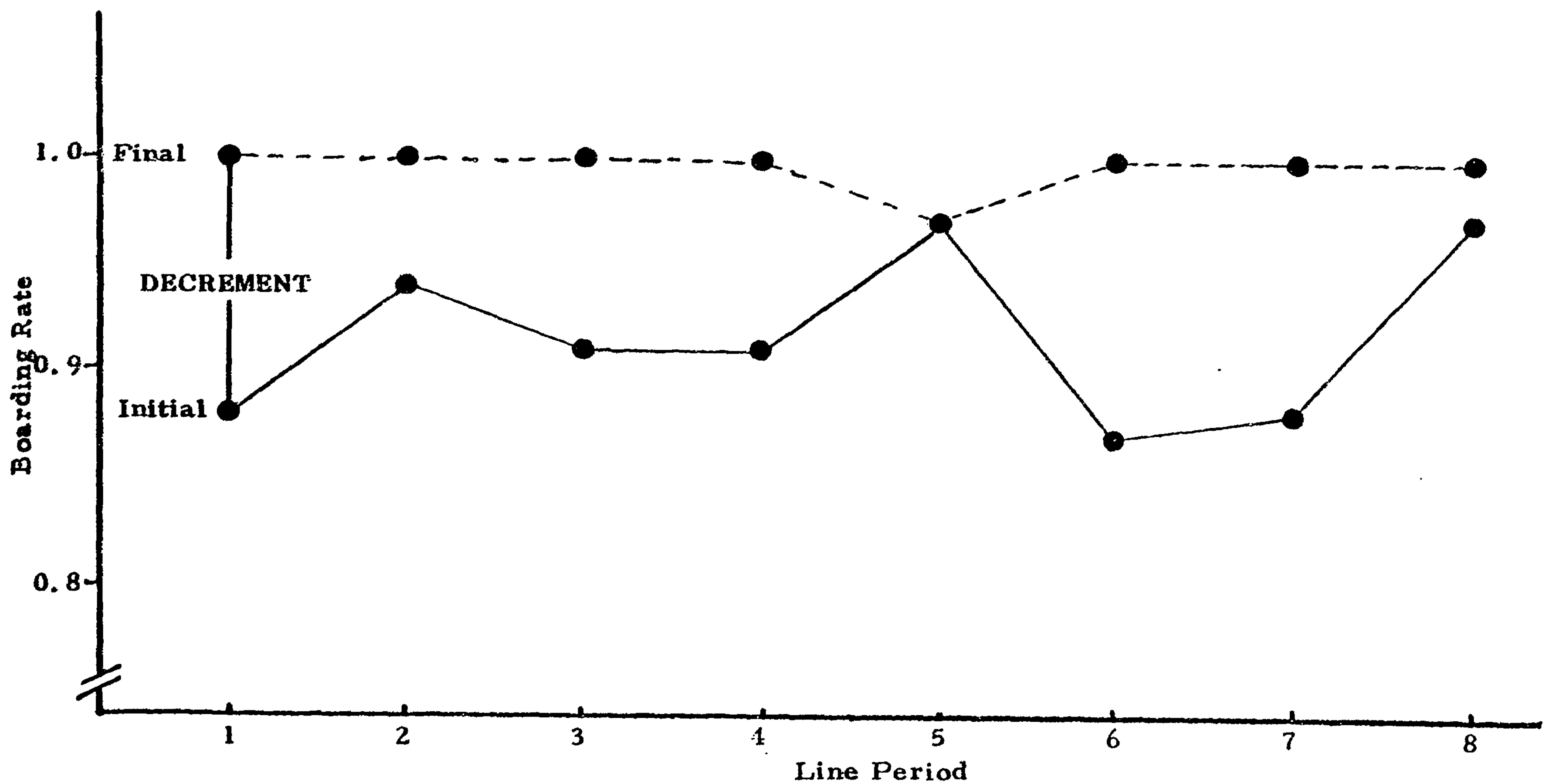
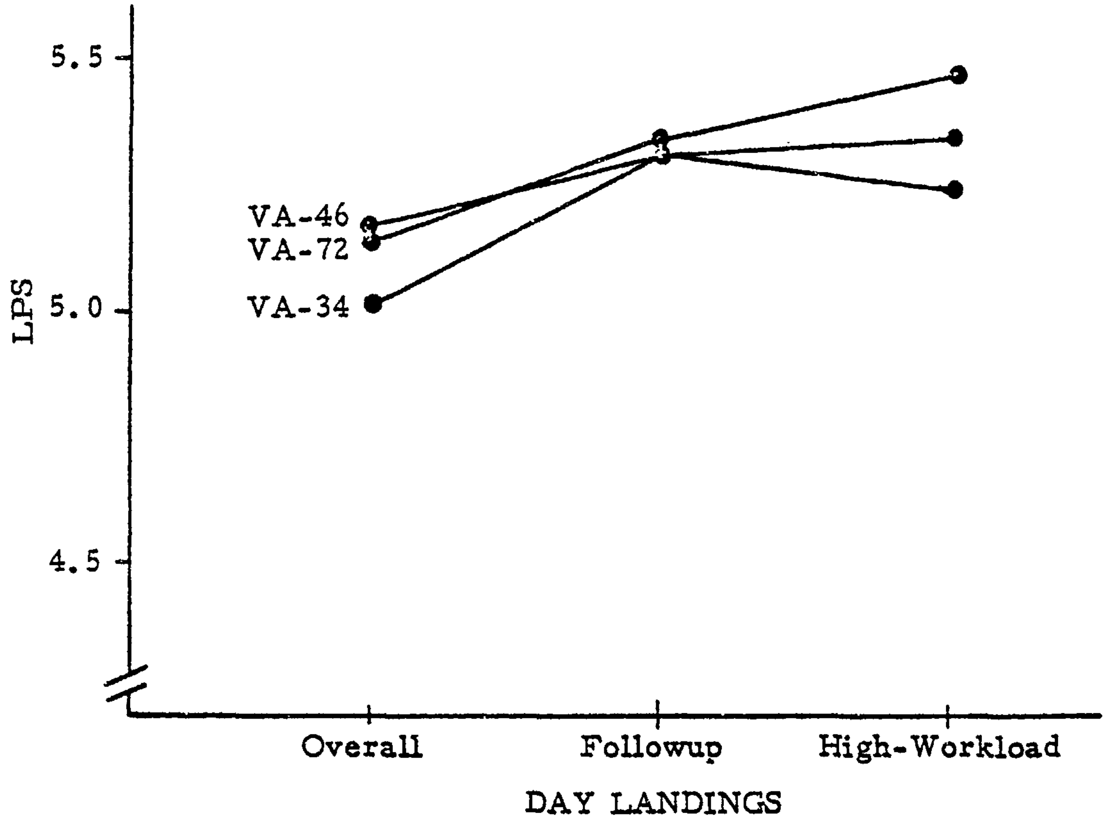


Figure A-3. Day boarding rate for all VA squadrons -- Beginning vs end of line period.



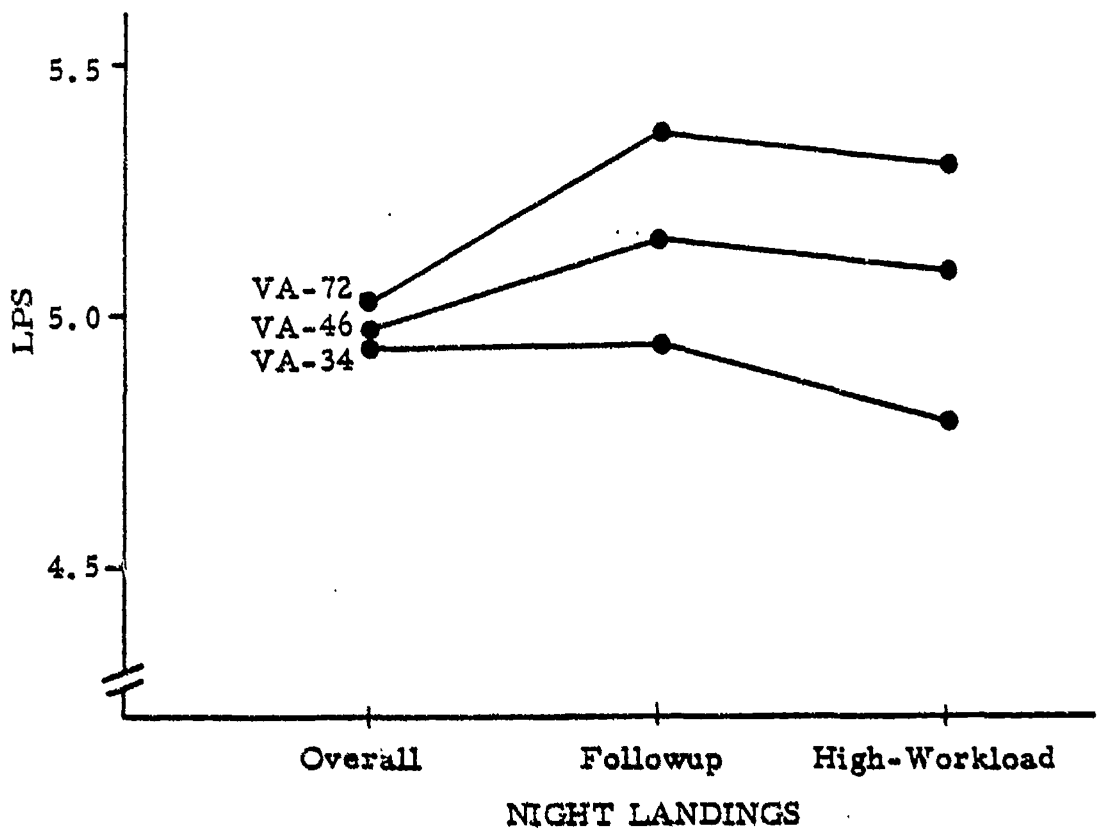


Figure A-4. Landing performance scores for day and night landings for three VA squadrons.

APPENDIX B

CARRIER QUALIFICATION (CQ) SAMPLE

FCLP

- Daily Activity - FCLP Workup
- Total Sleep in Twenty-Four Hours - FCLP Workup
- Sleep Episode Duration - FCLP Workup
- Distribution of Answers to Question: "How much trouble getting to sleep?" - FCLP
- Distribution of Answers to Question: "How well rested do you feel?" - FCLP

CQ

- Daily Activity - CQ
- Sleep Activity - RP, LSO and Shore Personnel
- Total Sleep in Twenty-Four Hours for Three Groups of Navy Personnel
- Sleep Episode Duration Across Three Navy Groups

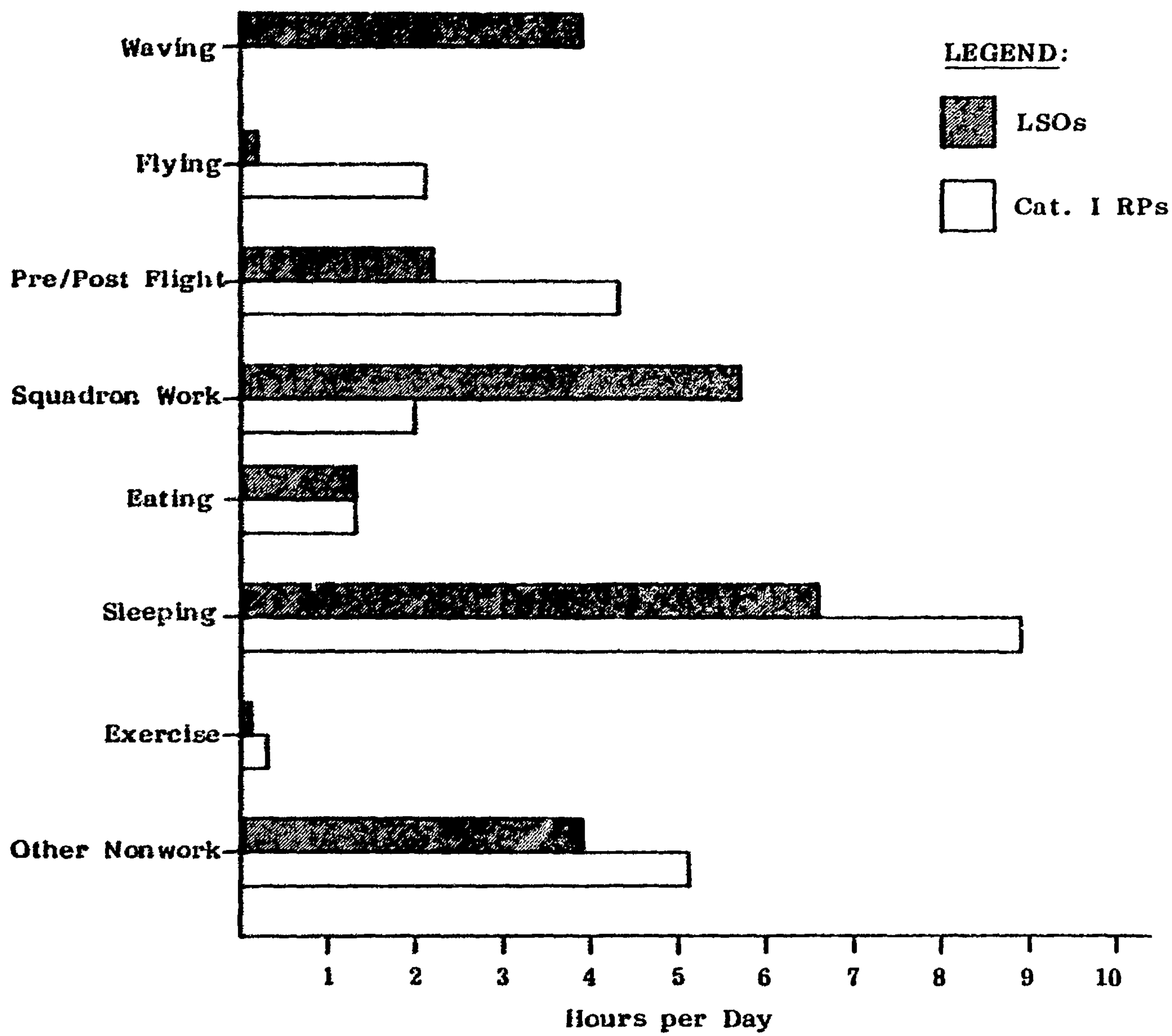


Figure B-1. Daily Activity -- FCLP Workup.

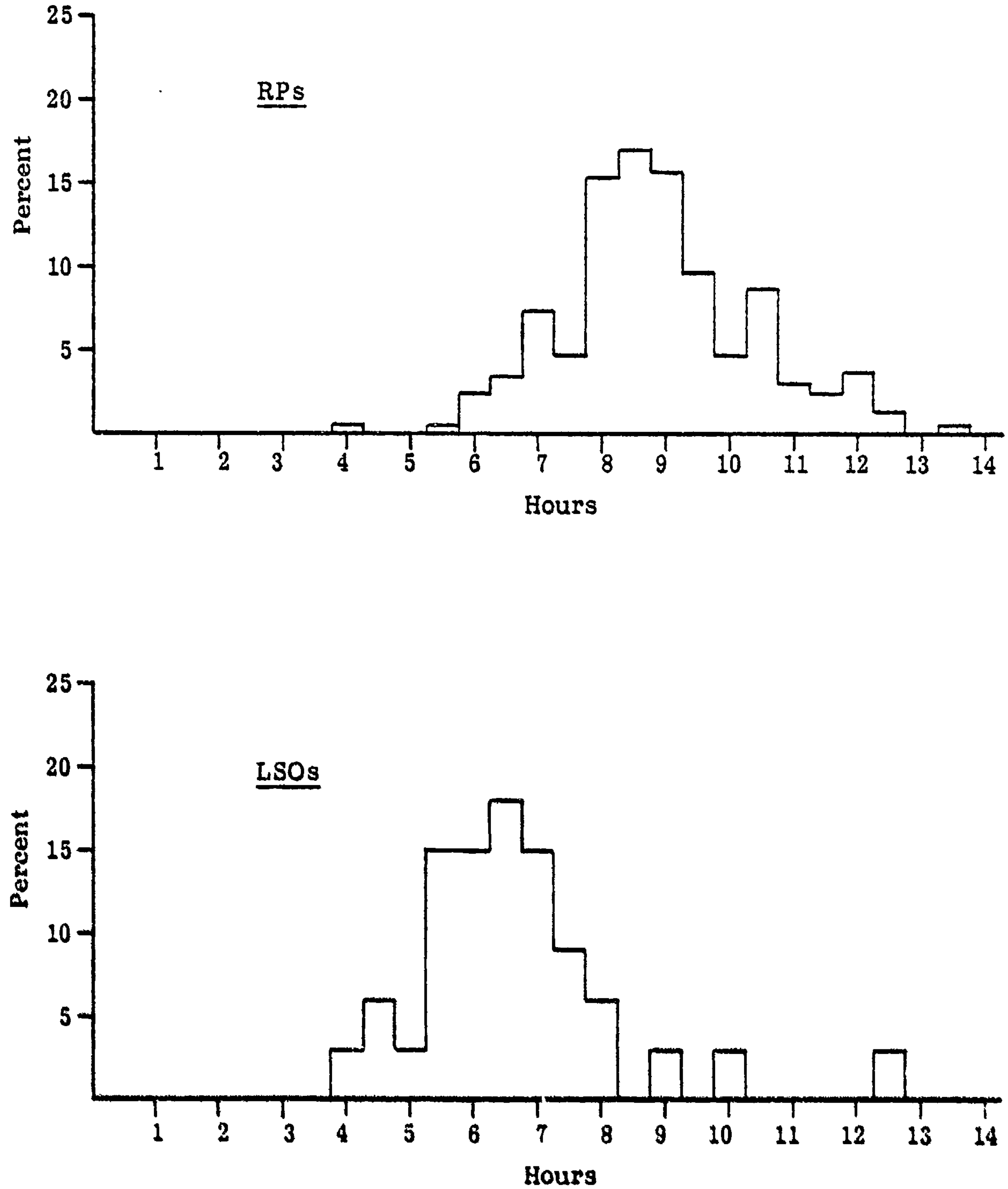


Figure B-2. Total Sleep in 24 Hours -- FCLP Workup.

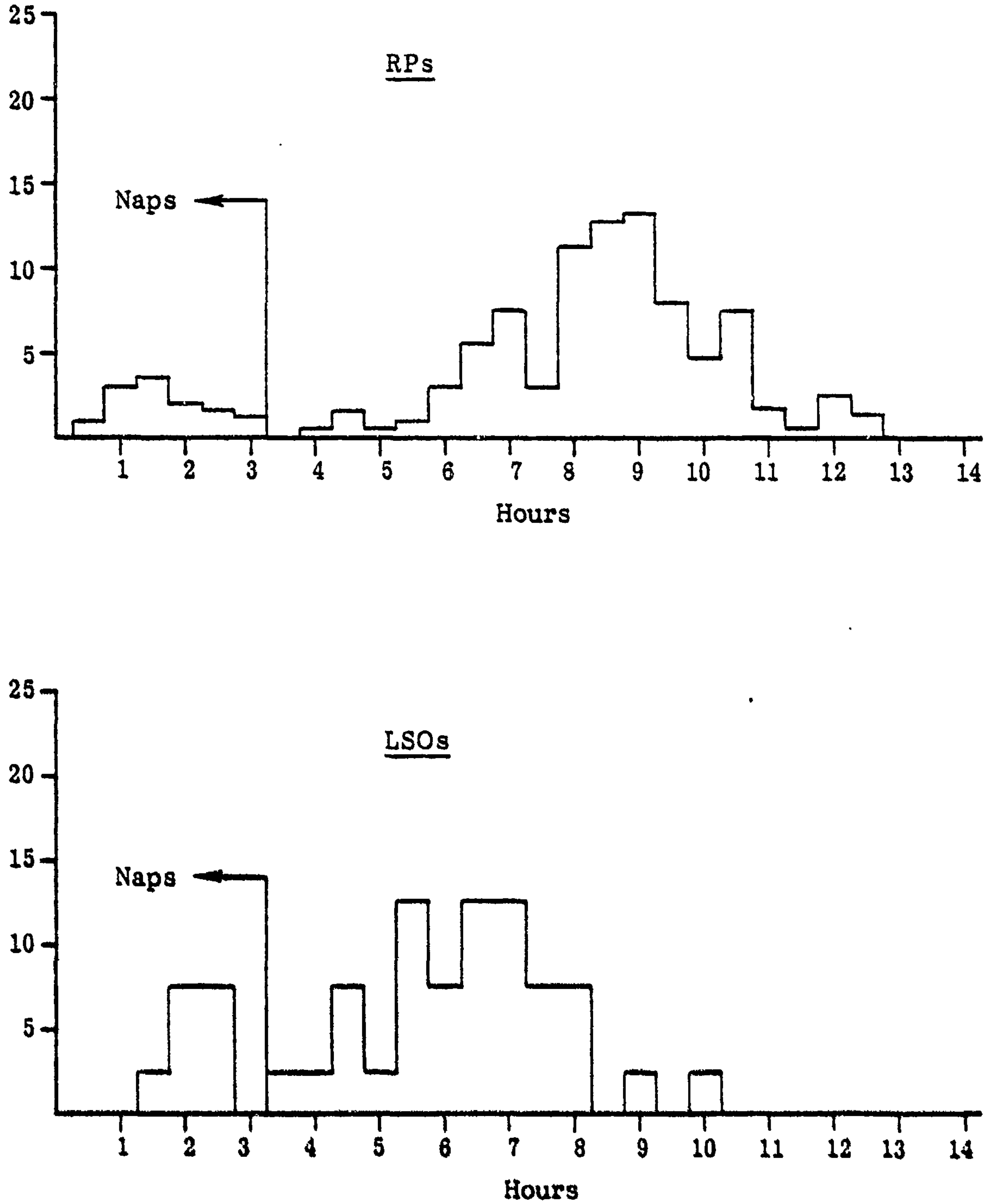


Figure B-3. Sleep Episode Duration — FCLP Workup.

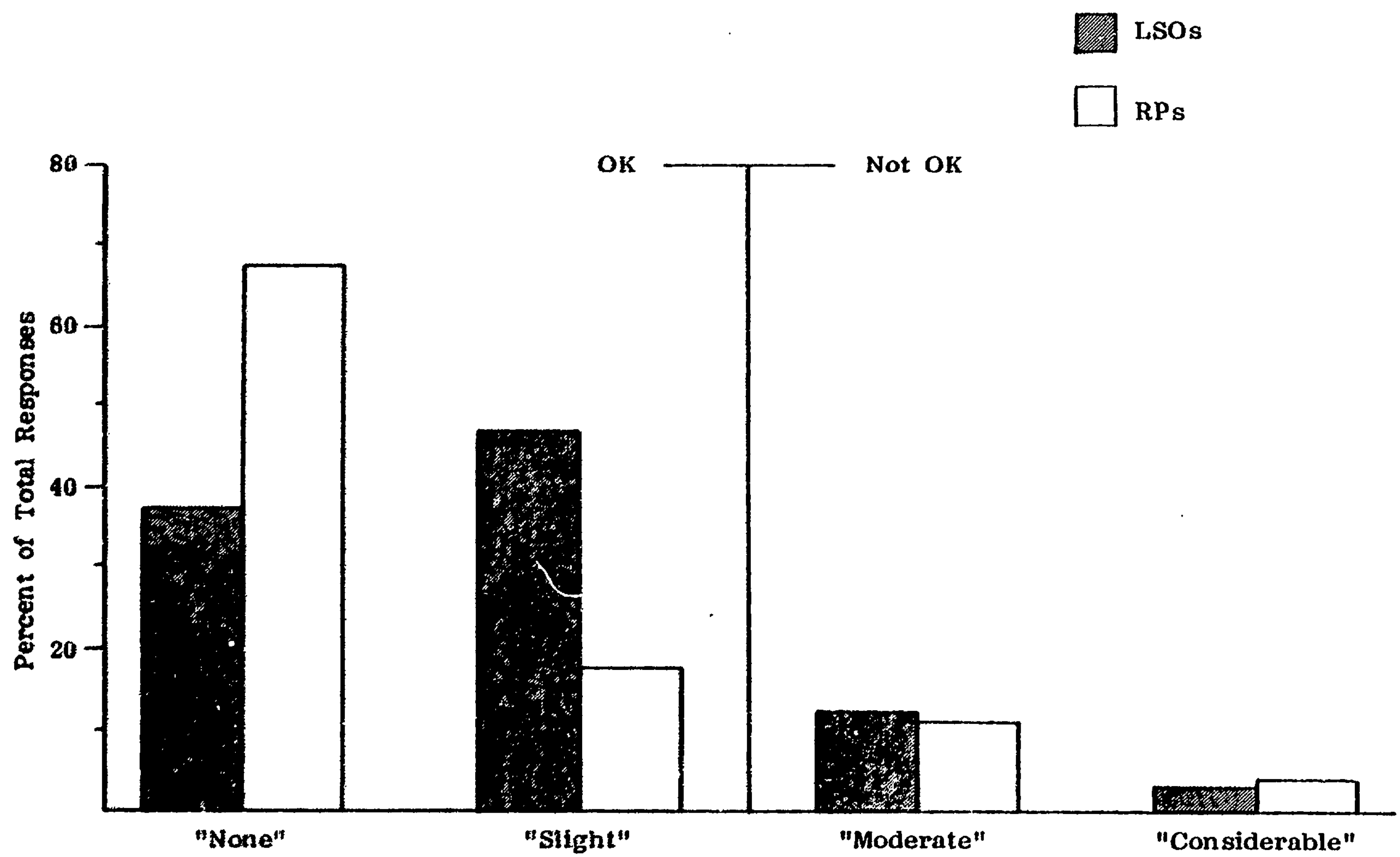


Figure B-4. Distributions of Answers to Question: "How Much Trouble Getting to Sleep?" (FCLP Work-Up)

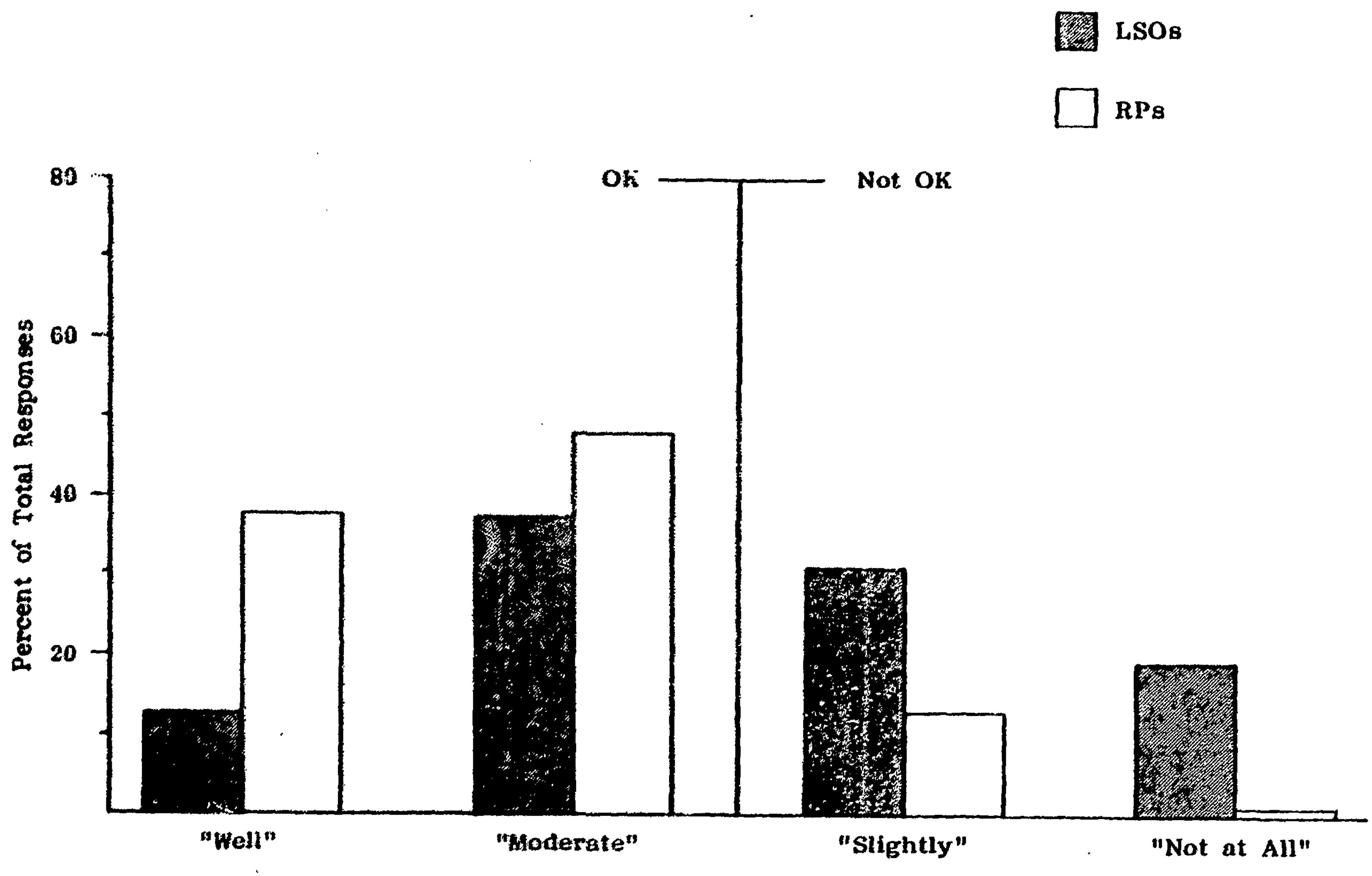


Figure B-5. Distributions of Answers to Question: "How Well Rested do You Feel?" (FCLP Work-Up)

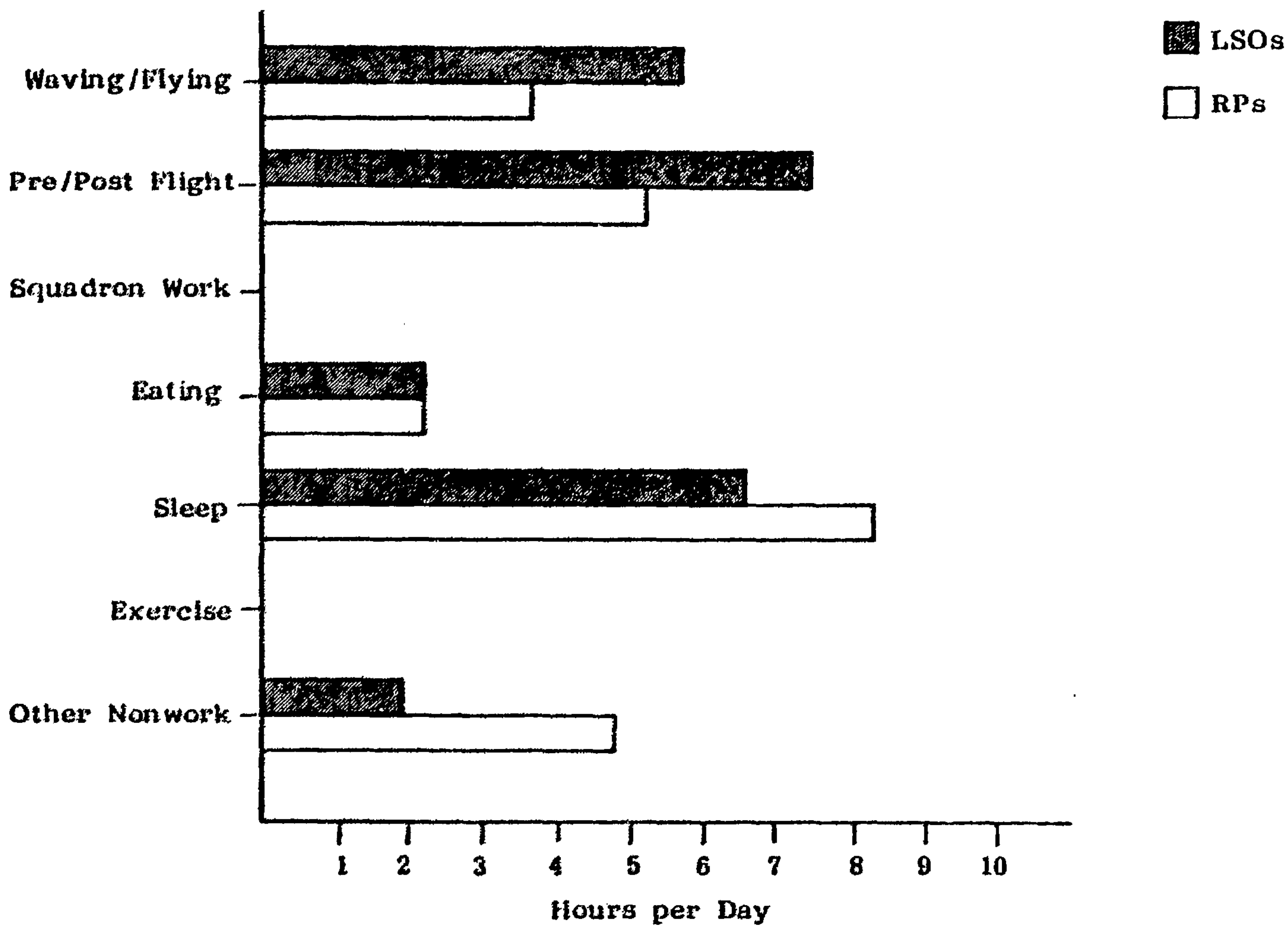


Figure B-6. Daily Activity (Shipboard CQ)

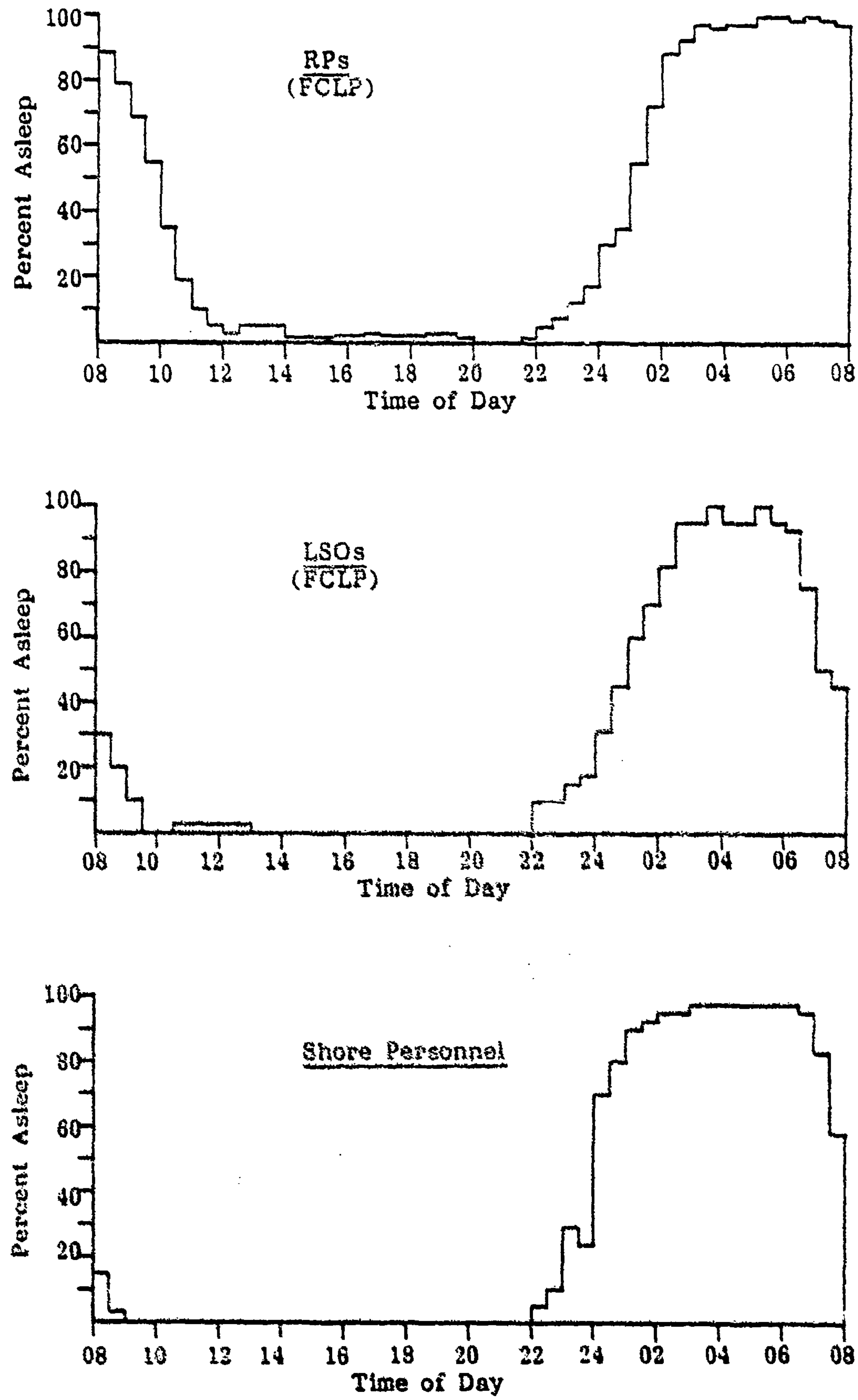


Figure B-7. Sleep Activity -- RP and LSO (FCLP) vs Navy Shore Personnel.

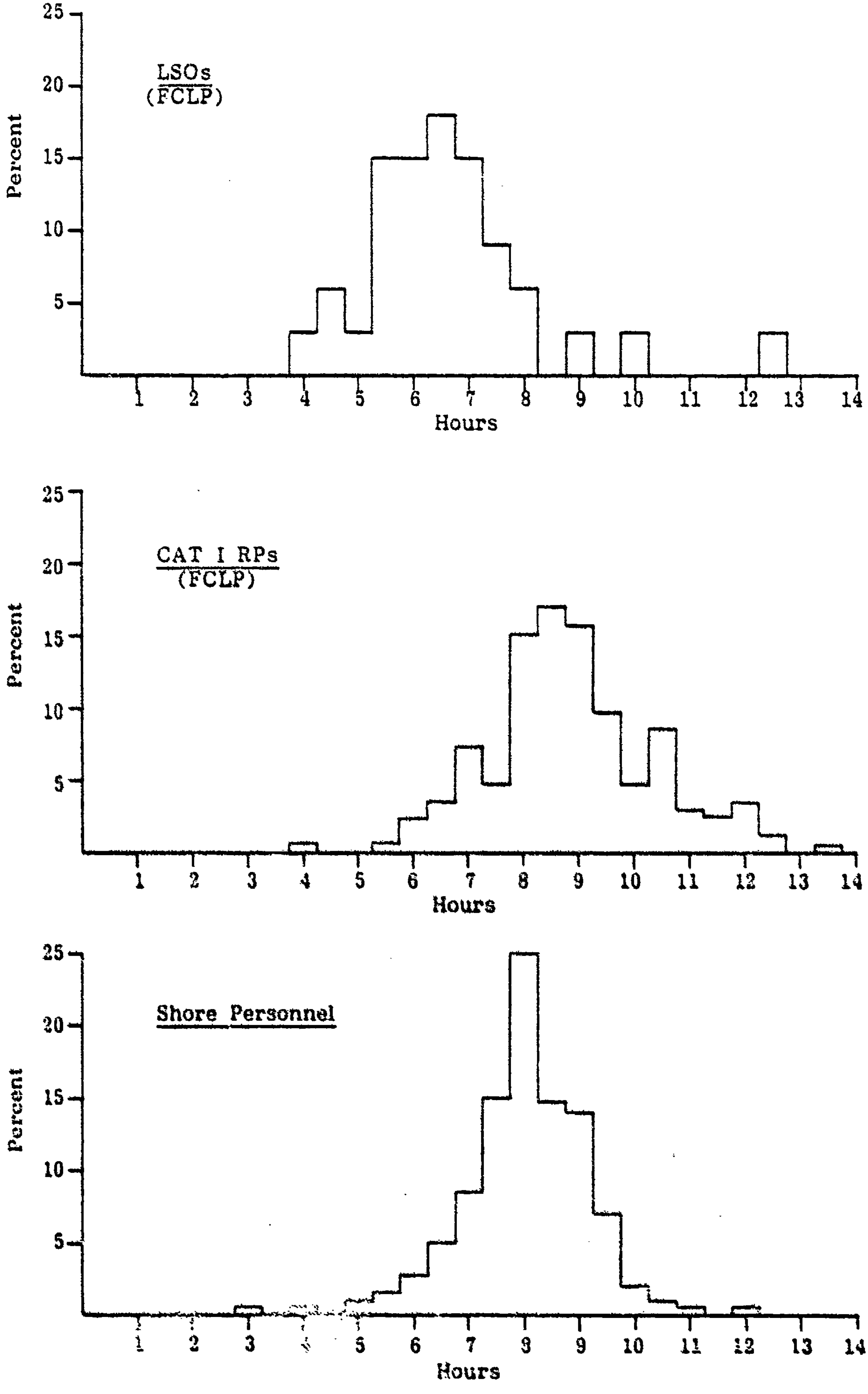


Figure B-8. Total Sleep in Twenty-Four Hours for Three Groups of Navy Personnel.

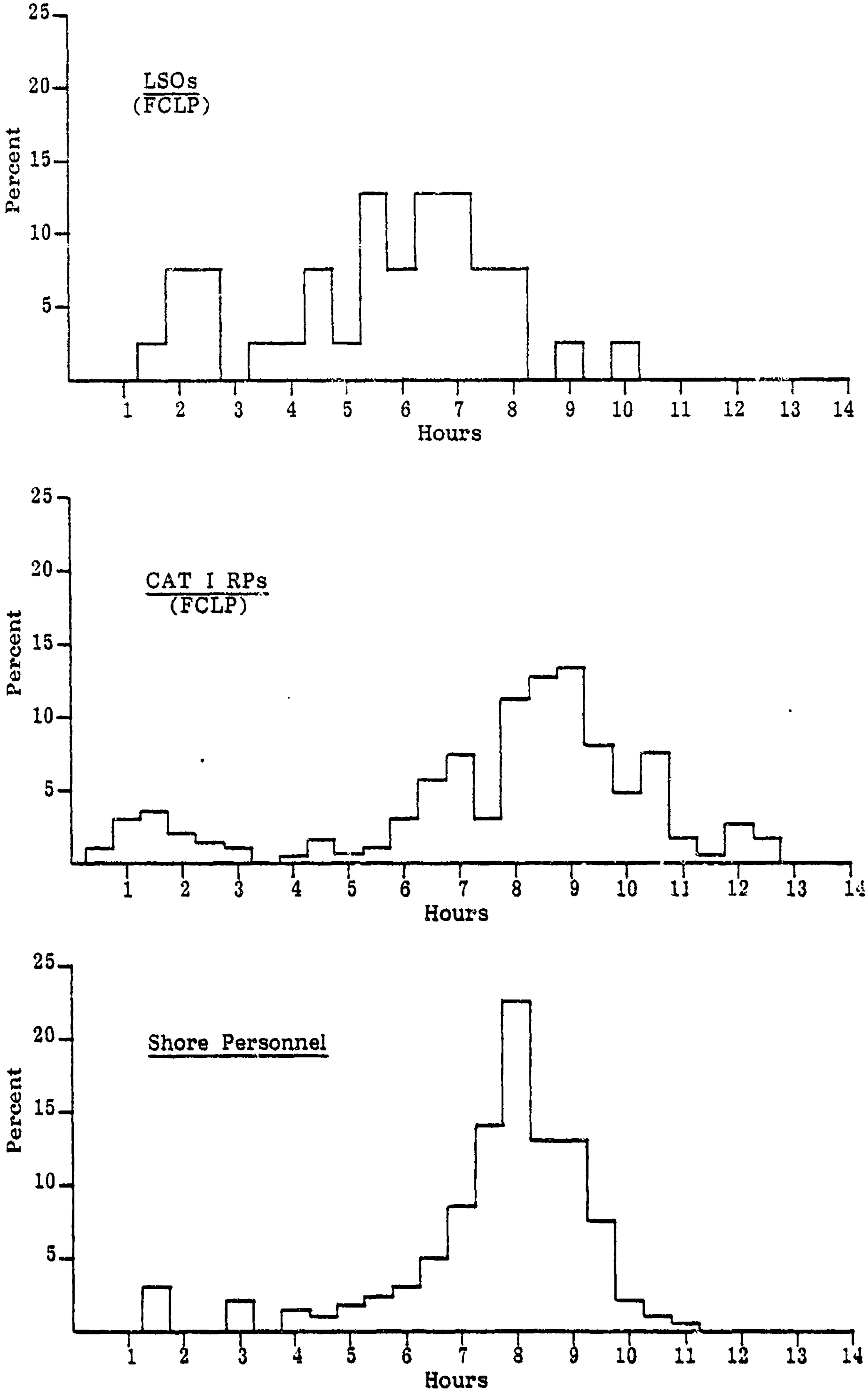


Figure B-9. Sleep Episode Duration Across Three Navy Groups.

APPENDIX C

TEMPORAL INDICATORS OF NIGHT LANDING PERFORMANCE DECREMENT

Pilot Landing Performance

Initial analysis of data collected during the deployment sample revealed very high levels of proficiency in carrier landing performance. These consistently high performance levels are noteworthy in their own right, but unfortunately do not provide an appropriate data base for studying the effects of workload and temporal variables on performance. Simply stated, the consistently high levels of performance all but precluded study of performance variation, since variation was almost nonexistent.

"Poor" Performance Defined: For the purposes of further elaboration, night carrier landing performance was examined to isolate incidents of notably poor performance within the sample. The LPS was used as criterion and those individual landings which scored as 3.5 or below were classed as "poor." Three distinct landing types are in this category:

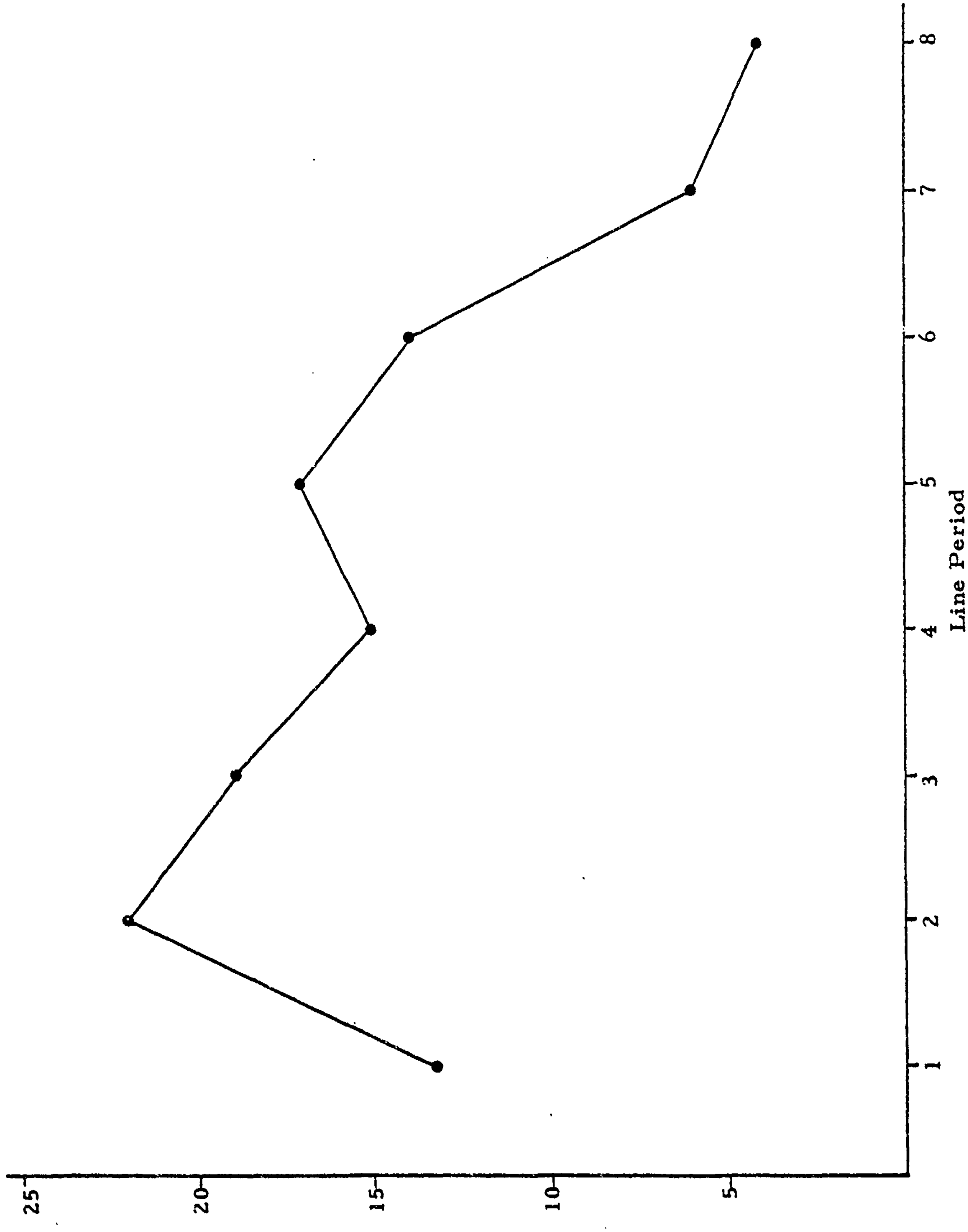
(a) Technique Wave-off (LPS score = 1.0)

(b) Bolter (LPS score = 2.0)

(c) Number One Wire Arrestment (LPS score = 3.5)

These types were selected because they represent "out-of-tolerance" performance in landing.

Frequency of Poor Performance: Figure C-1 shows the relative frequency of "poor" night landing performance as measured for eight line periods during the KENNEDY deployment. As can be seen, although poor performance levels were recorded for 14.1 percent of all night landings over the full deployment, the proportion of out-of-tolerance landings varied considerably from a maximum of 22 percent to a low of four percent. Further, a distinct and virtually steady decline in error rate over time is


Percent of all Night Landings
25
20
15
10
5
1
2
3
4
5
6
7
8
Line Period

apparent. Figure C-2 shows the inverse of this, plotting "acceptable" performance over time. This trend is consistent with the general increase in performance levels noted over the full cruise in previous analyses.

Frequency Distribution of Performance: It is of incidental interest to examine the distribution of performance across landing types. Figure C-3 shows the relative frequency of the six categories in the LPS. Within the three categories classed as "poor" performance, distributions are shown below:

Landing Type	% of all landings	% of "poor" landings
Wave-off (LPS = 1.0)	1.5%	10.7%
Bolter (LPS = 2.0)	5.7	40.2
One Wire (LPS = 3.5)	6.9	49.1
TOTALS	14.1%	100.0%

Temporal Indicators

One objective of this research was to explore and evaluate possible relationship between certain temporal variables and pilot performance. Variables considered include sleep patterns and duration, work and daily activity, and mood levels. Because of the consistent overall high levels of performance recorded for this sample analysis of the effects of any variables on performance was difficult. Incidents of poor performance were rate events, and comprehensive or conclusive analysis of performance variation was not possible.

Case-by-case Interpretation of Temporal Variables: Some clues to relationships between temporal variables and performance variation might be extracted from analysis of those cases of poor landing performance that were recorded during the sampling period. At the very least, inspection of the characteristics of these cases might provide a tentative basis for further exploratory research.

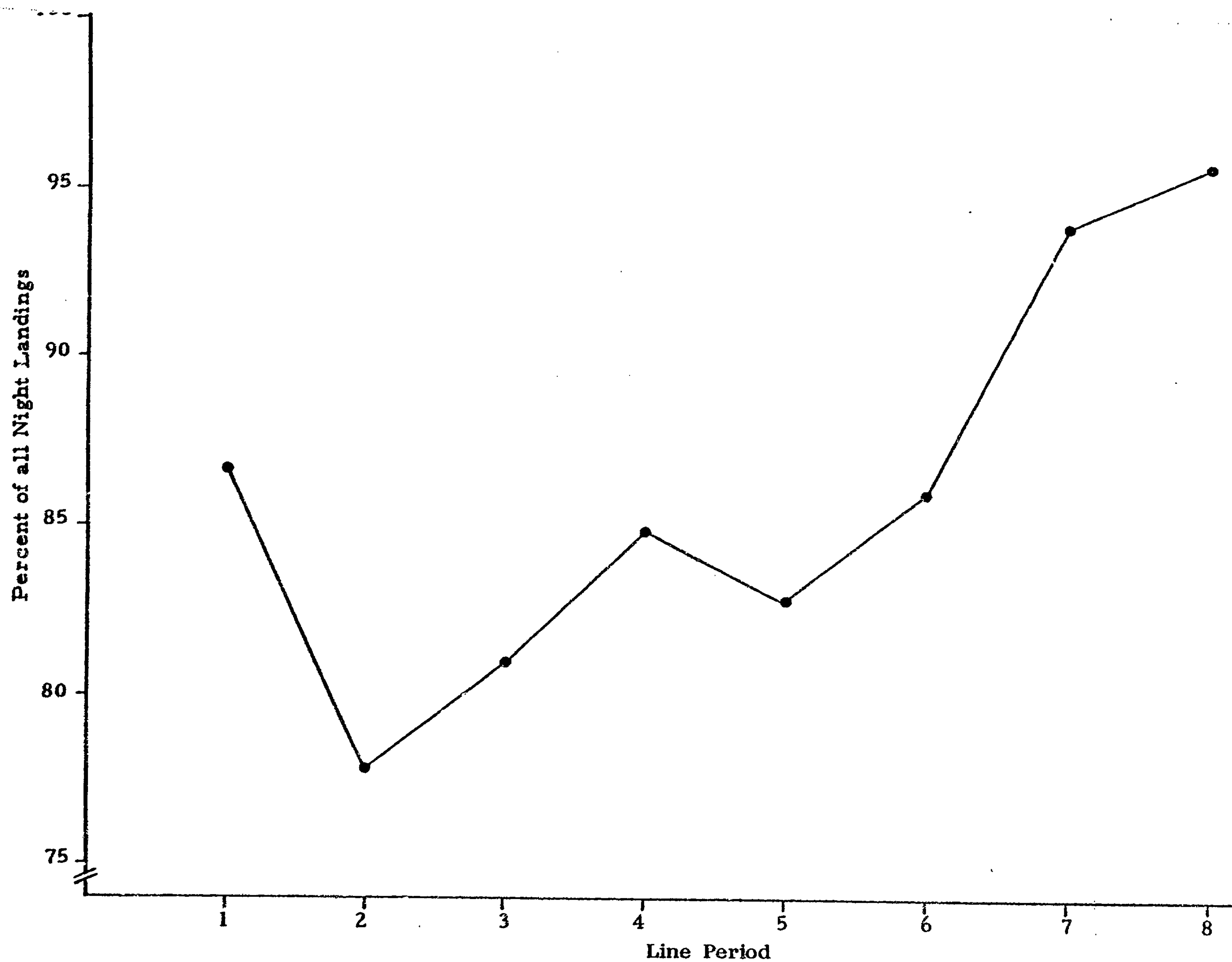
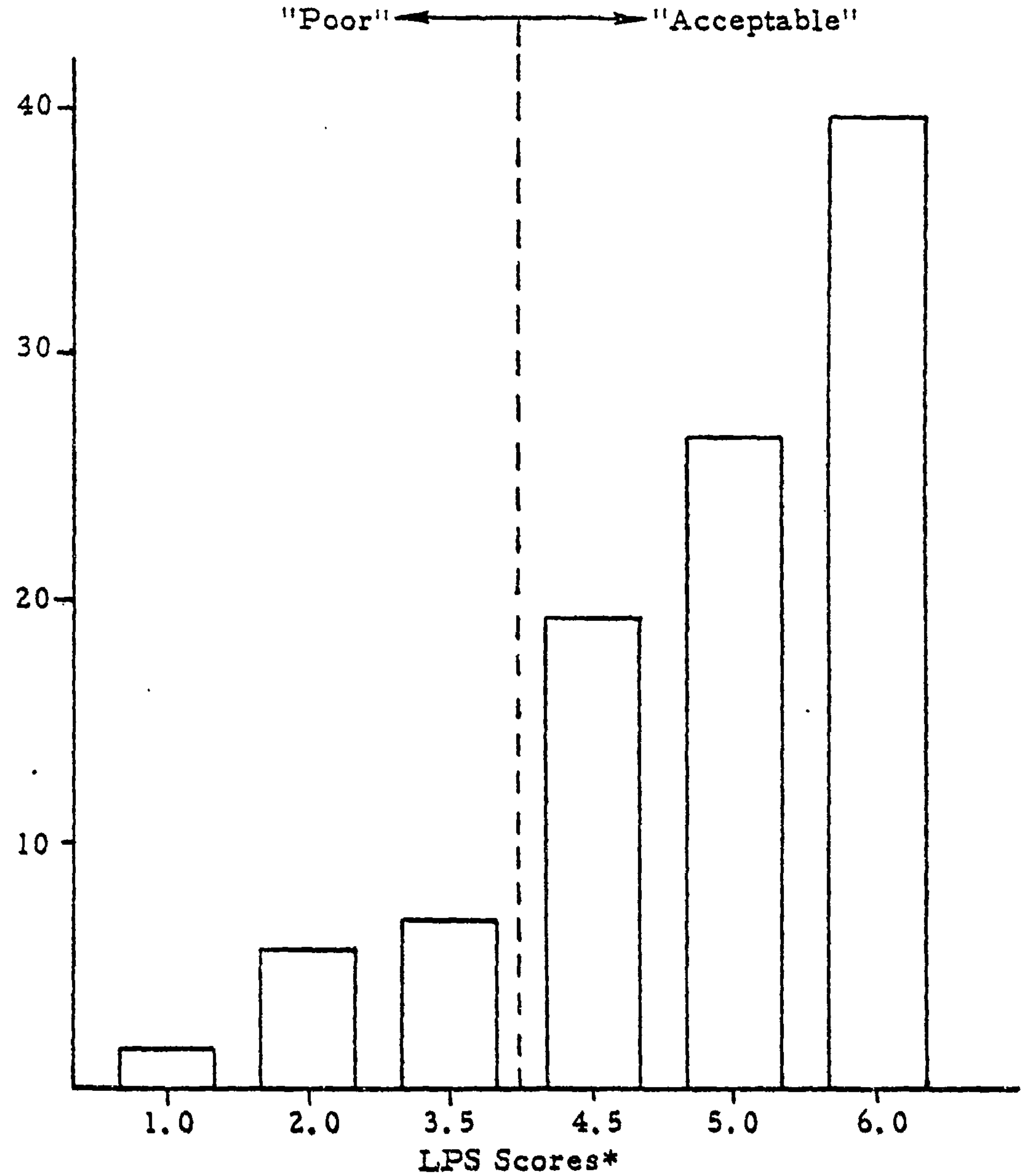


Figure C-2. Night Landing Learning Curve: Proportion of "Acceptable" Landings per Line Period



*LPS LEGEND:

1.0 = Wave-Off
2.0 = Bolter
3.5 = #1 Wire Arrestment
4.5 = #4 Wire Arrestment
5.0 = #2 Wire Arrestment
6.0 = #3 (Target) Wire Arrestment

Figure C-3. Relative Frequency Distribution of Night Landing Performance Scores -- Full Cruise.

Mood and daily activity data were collected for a sample of KENNEDY pilots during the final at-sea period of the ship's deployment (Line Period #8). Four incidents of out-of-tolerance night landing performance were recorded in this period. Four different pilots were involved, one of whom (subject #141) did not participate in the followup study, although he had been a part of the baseline data sample. The four cases and pertinent temporal data are listed in Table C-1.

Inspection of the data in Table C-1 reveals several possible areas for further study. When factors of daily activity and sleep patterns are examined, it can be seen that two of the pilots (#131 and #142) reported normal or near-normal sleep during the 24- and 48-hour periods preceding poor landings. Both, however, flew an extraordinary number of flight hours in those periods. In contrast to this pattern, subject #148 reported only nine hours sleep over the 48 hours prior to his wave-off. He reported only three hours of flight time for that day, but had not flown at all in the previous two days.

Comparison of mood scales for two pilots (#131 and #142) with similar sleep and flight activity highlights other similarities. For the Activity scale, both pilots scored a '7,' significantly lower than their Followup period averages and among the lowest levels for that scale reported by each. Both also showed similarities in scoring the Fatigue scale, recording scores that were much high than normal on those days when they performed poorly.

Subject #131 reported very high scores on both the Anger and Depression scales for his poor performance day; these scores were, in fact, the highest he reported on those factors during the entire Followup period. Scores for subject #142 were not notably different for these scales on the day he bolters. Unfortunately, mood scales were not collected from subject #141, and were not reported by subject #148. (Non-report, per se, might be some indication of mood state.)

TABLE C-1. SLEEP, FLIGHT HOURS, AND MOODS FOR FOUR VA PILOTS.

Subj.	Lndg.	Hours of Sleep				Flight Activity			Mood Comments				
		Last 24	Last 48	Baseline (hr/da)	Followup (hr/da)	Last 24	Last 48	Followup (avg/da)	Scale	Day's Score	Followup Avg.	Rank	Baseline Avg.
131	#1 Wire	10	15	7.4	8.5	6.5	12.0	3.5	Activity	7	8.25	7 of 8	6.9
									Anger	11	7.9	1 of 8	8.3
									Depress.	14	7.9	1 of 8	9.9
									Fatigue	10	8.75	2 of 8	10.3
141	#1 Wire	N/A	N/A	6.6	N/A	N/A	N/A	N/A	Not in Followup Sample				
142	~~B7~~	8.5	16	7.6	8.2	5	9.5	3.0	Activity	7	10.6	8 of 8	11.3
									Anger	6	7.1	4 of 8	6.4
									Depress.	7	7.0	4 of 8	6.2
									Fatigue	12	6.1	1 of 8	7.8
148	WO	7	9	6.6	7.3	3*	3*	3.0	Activity	N/A	12**	N/A	11.6
									Anger	N/A	6	N/A	6.0
									Depress.	N/A	6	N/A	6.1
									Fatigue	N/A	6	N/A	6.6

*No flights previous two days.

**Followup mood data for 1 day only.

Implications for Future Research

Although no conclusive results could be obtained from the present data, several tentative conclusions can be drawn that form the basis for recommendations for future data collection and analysis.

Sampling: One finding of this report is that temporal data were collected during deployment at that point when performance was least variable. Temporal data were obtained during the high levels of flight activity which, in this case, happened to be the last line period of the cruise. Table C-2 illustrates this point, showing that the proportion of poor performance was highest at the beginning of the deployment, and dropped almost steadily over the course of time. Assuming that this pattern is not atypical, several alternatives for future data collection can be addressed:

(1) Collect complete activity and mood data throughout the deployment. While this could severely affect the participation of subjects, and would present problems in data transcription and reduction, it would be ideal to obtain.

(2) Collect complete activity and mood data during selected line periods. This method would alleviate somewhat the problems mentioned above, but might also pose additional logistic difficulties.

(3) Collect activity and mood data on a selected 'matched pair' basis. This method calls for daily monitoring of carrier landings. When a poor approach is observed, that pilot is requested to fill out an activity/mood questionnaire. Similar data are collected on good performance days in order to obtain a matched set of data. Subjects act as their own controls, and all poor performance incidents can be included for study. This method would require an on-site monitor to follow performance and collect test and control data.

(4) Collect activity and mood data during special operation periods. This method would not follow a complete carrier deployment cycle, but rather would collect data during carrier qual, ORE/ORI, or fleet exercise periods. Although these periods do not

represent typical deployments, there are conceivably those times at which performance would be most variable and most sensitive to the influences of temporal variables. Personnel commitments for these periods would be minimal in contrast to other plans.

Temporal Variables Affecting Performance: Because of the lack of performance variation only promising trends can be drawn from the data base available at this time. Specifically, three major categories merit further exploration:

(1) Sleep: Sleep patterns and duration have historically been linked to performance variation. One of the three subjects displaying poor performance had reported only nine hours total sleep in 48 hours. Sleep data should continue to be collected for any new samples.

(2) Flying Activity/Workload: Two of the three poor performers reported nearly twice their normal number of daily flight hours. This was true for periods 24 and 48 hours preceding the poor landings. The other pilot had not flown during the two days before his wave-off. Activity data should be collected to compare relative work and sleep data across sustained operational schedules.

(3) Reported Moods: The two pilots who reported moods for the Followup sampling period show similar mood patterns on the Activity and Fatigue scales. One of these two also showed significant variation in his Anger and Depression scales as well.

Combinatorial effects of the above should not be ignored. As an example, subject #148 experienced night landing difficulty after having only nine hours sleep in two days. At the same time, he had not flown in the two preceding days. In the two other cases, heavy flying workloads coincided with unusually high feelings of Fatigue, but unusually low reports on Activity.

In conclusion, the data covered here can provide the basis for: 1) planning a comprehensive and effective data collection effort in the near furture, and 2) exploratory analysis of certain temporal variables which might affect performance.

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